

A QUASI-EXPERIMENTAL EXAMINATION OF THE EFFECTS OF COGNITIVE  
SEQUENCING ON STEM CONCEPT INTEGRATION IN AGRICULTURAL  
EDUCATION

A Dissertation

by

KASEE LYNN SMITH

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Chair of Committee,	John S. Rayfield
Committee Members,	Tim H. Murphy
	Robert Strong
	William David Reed
Head of Department,	John “Jack” Elliot

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## ABSTRACT

Understanding the best methods for effectively instructing STEM education concepts is essential in the current climate of education. Kolb's experiential learning theory outlines four specific modes of learning, based on preferences for grasping and transforming information. This quasi-experimental study was conducted to test the effect of cognitive sequencing of instruction through Kolb's experiential learning theory. The Principles of Agriculture, Food, and Natural Resources courses in four Texas high schools were randomly assigned to one of four experimental groups (N = 128).

Two units of instruction were developed, one in water science and one in soil science. Each content unit was developed in two separate sequences; one with each new concept presented beginning with a concrete experience and moving to an abstract conceptualization and the other beginning with abstract conceptualization and moving to concrete experience. Three sites served as test groups while the fourth site was a control group and did not receive exposure to the treatment. This experiment utilized a crossover design to allow each student to experience both cognitive sequences. The independent variables of cognitive sequence of instruction, socioeconomic status, learning disabilities, and student preference for grasping information were analyzed in relation to the dependent variables of student change score from pretest to posttest for both units of instruction.

The findings revealed no significant differences in change scores for the independent variables of socioeconomic status or learning disability. A significant interaction and large effect size was found between the independent variables of

preference for grasping information and cognitive sequence of presentation for both units of instruction. An examination of the simple main effects showed that students had significantly higher change scores when the information was presented beginning with the learning mode they showed preference for. These findings shed light on the importance of utilizing student preferences through experiential learning theory as an important factor in designing STEM curriculum and teaching STEM concepts in agricultural education.

## DEDICATION

This dissertation is dedicated to my family, for their tireless support of my endeavors (academic and otherwise), and to every agricultural educator who has ever tried to change the heart and minds of students.

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## CHAPTER I

### INTRODUCTION

Rigor, relevance, and relationships have given way to 21<sup>st</sup> century skills, critical thinking, and STEM education as the academic buzzwords driving educational reform (Maltese, Potvin, Lung, & Hochbein, 2014). In light of these educational pressures, and in an effort to provide insight into the role of agricultural education, this dissertation research has been conducted to analyze methods for better instructing Science, Technology, Engineering, and Mathematics (STEM) concepts within secondary agricultural education courses. This chapter will present the background information and outline the purpose and objectives used in my approach to the research topic.

#### **Background and Setting**

In the last ten years, there has been an increased focus on using education to prepare students for more than recall of basic information (Carnoy & Rothstein, 2013). This shift in focus is not without warrant. According to the World Economic Forum, the United States ranked fifty-first in quality of math and science education when compared to all nations worldwide (Schwab, 2011). Secondary students in the U.S. demonstrate declining comparative performance in STEM areas (Carnoy & Rothstern, 2013), and there are growing concerns that students are not completing their education with the skills and knowledge required to enter skilled careers (Maltese, et. al., 2014). Employers have expressed a need for education to prepare an American workforce that is ready to compete in a global marketplace, citing STEM concepts as an area of major deficit

(Maltese, et. al., 2014). These factors have combined to drive motivation for increasing focus on STEM concepts in American education.

STEM education has been a part of the culture of education in the United States since the National Science Foundation (NSF) coined the term in the early 2000s (Duggar, 2010). Researchers have found that many students, including at-risk and low achievers, have difficulty with STEM concepts like mathematics when taught in standalone courses, as they become too abstract for these students to understand (Boaler, 1998; Kieran, 1992; Woodward & Montague, 2002).

The highly abstract nature of many STEM concepts has led researchers to conclude that these topics are best taught in areas where additional context can be given to facilitate student learning (Boaler, 1998; Kieran, 1992; Stone, 2011; Woodward & Montague, 2002). Career and Technical Education (CTE) courses, including agricultural education, have been seen as a possible solution to teaching STEM concepts for all students, as these courses are more easily modified to deliver abstract content embedded within a contextual frame (Stone, 2011). In order to prepare agricultural students who are ready to meet current workforce requirements, agricultural education must promote the learning and retention of STEM concepts, through the most efficacious methods (Maltese, et. al., 2014).

While the vast majority of educational literature has led researchers to conclude that there should be increased focus on STEM concepts, there are differing views on the instructional strategies for teaching those concepts. In a 2007 report, the US Department of Education Academic Competitiveness Council concluded “there is a



general dearth of evidence of effective practices in STEM education” (pg. 3). This statement holds true for both instruction in standalone STEM courses and CTE courses with STEM integration. To more effectively integrate STEM concepts into all secondary classes, including agricultural science courses, research into effective practices must be conducted (Stone, 2011).

Effective education for any field of study, including STEM education, is rooted in the action of a student contextualizing abstractions (Garlick, 2010). The brain works through a system of cognitive linkages that are created in young minds, and refined throughout adulthood (Garlick, 2010; Sousa, 2011). By capitalizing on the way the brain naturally processes information and tying learning to the pre-existing model for experiential learning, agricultural educators may be better poised to help students understand even very abstract concepts, like many of those found in STEM education fields, while simultaneously stimulating higher-order thinking skills (Sousa, 2011).

Educational researchers and practitioners have spent a great deal of time and energy examining the importance of instructional methods in relation to student learning (Cronbach & Snow, 1981; Eggen, Kauchak, & Harder, 1979; Marzano, Pickering, & Pollock, 2001; Tallmadge & Shearer, 1971). There has been little experimental research conducted in agricultural education on the core psychological principles that these instructional methods are built upon. Single instructional methods are rarely used as standalone components of a class. Quality educators use multiple instructional methods during a given unit, and even within the same class period to help facilitate learning (Marzano, et. al., 2001). There are however, overarching principles of instruction that

can be manipulated to assess effectiveness in increasing student performance. One of those overarching principles is the concept of cognitive sequencing.

Agricultural education is rooted in experiential learning (Baker, 2012; Roberts, 2006). As agricultural educators work to effectuate student learning, they often use Kolb's (1984) experiential learning theory (ELT) as the model through which to deliver, reinforce, and evaluate student learning. One approach to understand how agricultural education might work to help resolve a disconnect between students and STEM concepts would be to examine effective methods for presentation of STEM concepts in agricultural education classes through the ELT model, which provides a framework for examining the sequencing of instruction.

Cognitive sequencing is the concept of presenting information in a systematic order based on predefined cognitive descriptors (Webb, 1997). In the realm of ELT, Kolb (1984, 2015) defines preferences for grasping information as a continuum between apprehension, defined as Concrete Experience (CE), and comprehension, defined as Abstract Conceptualization (AC). The concept of sequencing the initial exposure to instructional information from a specific end of the continuum has not been fully examined in the educational arena. Baker, Brown, Blackburn, and Robinson (2014) conducted an initial examination into presentation order of concepts within the context of experiential learning theory for post-secondary students using agriculture as the context. While their findings failed to reveal significant differences between order of abstraction and type of reflection, they recommended further research in this area, specifically within the secondary classroom.

Student performance on STEM assessments, like any academic assessment, is not likely to be controlled by one single factor. Meyers, Gamst, and Guarino (2013) posit that “rarely is one aspect of human behavior so isolated from other aspects of the overall response that it can paint a comprehensive picture of how someone responds to a situation” (p. 224). An examination of the literature revealed that of the numerous factors likely to influence student understanding of abstractions, those which likely play a large role and are realistic for inclusion in the scope of this project are learning style (Kolb, 1984, 2015; Zull, 2002), socioeconomic status (Sirin, 2005; White, 1982) and learning disabilities (Bender, 2007, 2008; Hampton & Mason, 2003).

The full examination of the sequencing of instruction through the prehension continuum of experiential learning theory lends itself to answering the question: what are the factors of influence for agricultural education student performance on assessments of STEM knowledge, and does cognitive sequencing through the frame of experiential learning theory play a role?

### **Statement of the Problem**

Career and Technical Education, including agricultural education, has been called upon to deliver STEM concepts in an applied setting. Research must be conducted into the most effective instructional practices to enhance student comprehension in STEM areas within CTE courses. To accomplish this, a comprehensive look into the factors that influence student performance on STEM assessments should be completed. Cognitive sequencing of instruction is likely to play a role in cognition (Garlick, 2010),

and different cognitive sequences must be causally tested to determine impact on student learning.

### **Purpose and Research Question**

The purpose of this study was to determine which cognitive sequence was most effective at impacting student performance on STEM content assessments in secondary agricultural education courses. To accomplish this purpose, the study worked to answer the following question:

1. What interactions exist between the factors of cognitive sequence, learning style, socioeconomic status, and learning disability on student performance on STEM content assessments in agricultural education?

The quasi-experimental component of this study was guided by the following null and alternate hypotheses:

H<sub>O</sub>1: There is no interaction between cognitive sequence, learning disability, socioeconomic status and learning style on STEM-based content assessment performance in agricultural education when cognitive sequence is manipulated.

H<sub>A</sub>1: Interaction exists between cognitive sequence, learning disability, socioeconomic status and learning style on STEM-based content assessment performance in agricultural education when cognitive sequence is manipulated.

As this quasi-experimental study identified the cognitive sequence which was most effective for students with specific characteristics, results allow for further action to

be taken in developing teacher education strategies to train pre-service educators, conduct professional development, and designing curriculum materials for in-service educators which highlight the most effective cognitive sequence for STEM integration in both agricultural education and other CTE courses.

### **Definition of Terms**

Definitions used in this research study included terminology commonly associated with STEM education in the United States and the pedagogical study of experiential learning. Operational definitions utilized in this research include:

1. Agricultural Education: program of instruction in and about agriculture and related subjects (Talbert, Vaughn, Croom, & Lee, 2007, p. 4).
2. Apprehension: “the process of grasping or taking hold of experience in the world through a reliance on the tangible, felt qualities of immediate experience” (Kolb, 2015, p. 67).
3. Career and Technical Education (CTE): “Organized educational activities that offer a sequence of courses that provides individuals with coherent and rigorous content aligned with challenging academic standards and relevant technical knowledge and skills needed to prepare for further education and careers in current or emerging professions” (Carl D. Perkins Act of 1998, p. 1)
4. Cognitive Sequencing: presenting concepts during instruction in purposively determined sequences (James, 1912; Kolb, 1984, 2015).

5. Comprehension: “the process of grasping or taking hold of experience in the world through a reliance on conceptual interpretation and symbolic representation” (Kolb, 2015, p. 67).
6. Engineering: the application of mathematics and sciences to develop ways to utilize the materials and forces of nature to benefit mankind (ABET, 2002).
7. Experiential Learning: “a process whereby knowledge is created through the transformation of experience” (Kolb, 2015, p. 49)
8. Experiential Learning Theory: “a dynamic views of learning based on a learning cycle driven by the resolution of the dual dialectics of action/reflection and experience/abstraction” (Kolb, 2015, pp. 50-51).
9. Instructional Method: “a systematic plan followed in presenting material for instruction” (Marzano, et. al., 2001).
10. Learning: the action of conceptualizing abstractions for recall and application (Gagne, 1962).
11. Learning Disability: “a condition giving rise to difficulties in acquiring knowledge and skills to the level expected of those of the same age, especially when not associated with a physical handicap” (Bender, 2008, p. 18).
12. Mathematics: “the science of patterns and relationships” (AAAS, 1993, p. 23).
13. Prehension: a dialectic dimension within experiential learning theory which is based on the tension between grasping experience through concrete experience and abstract conceptualization (Kolb, 2015).

14. Science: “deals with and seeks the understanding of the natural world” (NRC, 1996, p. 24).
15. School Climate: the quality and character of school life (Cohen, McCabe, Michelli, & Pickeral, 2009, p. 181).
16. Socioeconomic Status: “cultural standing of a student influenced by family income, parents’ education, and parents’ occupation” (White, 1982, p. 461).
17. STEM Education: cross-disciplinary education which includes instruction in the constructs and comprehension of concepts related to science, technology, engineering, and mathematics (Dugger, 2010).
18. Technology: “the modification of the natural world to meet human wants and needs” (ITEA, 2000, p. 7).
19. Thinking Skills: “cognitive strategies required to connect tacit information to contextual understanding” (Zohar & Dori, 2003).

### **Limitations of the Study**

Although research was conducted with predetermined mechanisms for retrieving the most accurate information related to each objective, several limitations exist based on the nature of this study. Limitations to this study included;

1. Participants in this study were secondary agricultural education students enrolled in existing Principles of AFNR classes in Texas. It is important to note the nature of the predetermined population and implications for generalizing this information to agricultural students as a whole.

2. Inability to control for all extraneous variables related to individual students in the experimental component of the study. It was not the intent of this study to conduct this research in a clinical setting. According to Shadish, Campbell, and Cook (2002) “experiments make a contribution when they simply probe whether an intervention-as-implemented makes a marginal improvement beyond other background variability” (p. 489). Extraneous student variables exist in all classrooms and are not within the scope of the educational system to mediate (Shadish, et. al., 2002). To control for this limitation, the experiment was conducted using a repeated measures crossover design (Campbell & Stanley, 1963; Shadish, Cook, & Campbell, 2002), allowing each student to be exposed to each treatment and provide an individual comparison of effects. Additional threats to validity and resulting design factors taken to address threats will be discussed in Chapter Three.
3. Differences in teacher test administrators. Differences in teacher abilities and skill levels were factors which may have influenced results. To control for this, all Texas agricultural science teachers participating in this study received detailed training in the appropriate techniques for the delivery of each cognitive sequence and signed agreements of compliance to research procedures. In addition, experimental groups were randomly assigned to treatments. In addition, information related to the background of teachers was collected and reported.



4. Student absences could have contributed to students not receiving information.

To control for this, data from all students missing more than 20% of instructional days in each unit of instruction was excluded from that round of testing (Jurs & Glass, 1971).

5. The specific content areas of water science and soil science may have led to differing prior knowledge in students with regard to the background knowledge of science concepts within these units. Pretest differences between sites were examined and reported. While the use of a pretest allowed a baseline of knowledge to be determined, caution should be taken when inferring the results of this study to other STEM content settings.

### **Basic Assumptions**

The following assumptions about data collection were assumed to be true. As such, no documentation verifying this data was collected, and the following assumptions will be included within the parameters of this research:

1. Teachers administering the instructional units taught the units following the lesson plans within experimental curriculum exactly as written. Teachers participating in this study received training in the proper use of the curriculum and instruction on the specific factors of cognitive sequencing.
2. Students participating in the study were secondary students enrolled in a Principles of Agriculture, Food, and Natural Resources course at one of the participating sites in the 2015-16 school year in Texas.

3. Students completed assessments of STEM concepts based on their level of understanding.
4. Students completed the KLSI accurately and with answers representative of their learning preferences.
5. Information obtained related to student socioeconomic status, and learning disability status was accurate.

### **Significance of the Problem**

Researchers conducting a 2007 study in conjunction with the United States Department of Education Academic Competitiveness Council concluded that there was a decided lack of knowledge about effective practices for STEM concept integration (Stone, 2007). This revelation brought to light the issue that while the vast majority of educators are in favor of integrating STEM concepts into courses outside of the academic core (Maltese, et. al., 2014), little research has been conducted to determine the most effective way to deliver information to students in order to enhance learning. In fact, Stone (2007) stated that in a comprehensive search into the literature surrounding STEM integration and teacher practices that “little rigorous research exists to inform policy about what might actually improve education in STEM disciplines” (p. 13).

The nature of cognitive functioning leads to differences in the way students grasp information (Garlick, 2010; Sousa, 2011). Through experiential learning theory, Kolb posits there are two distinct modes of grasping experience; grasping via apprehension, which involves tangible, immediate concrete experiences or grasping via

comprehension, which involves interpretation and abstract conceptualization (Kolb, 2015).

Although student preferences for learning can be assessed through an inventory of learning style, experts have agreed that learning style is highly influenced by personal factors (Duff, 2004; Dunn & Dunn, 1989; Gregorc, 1979; Kolb, 2015). Two of the influences which repeatedly surface in the literature and are believed to impact student differences in learning style and student learning are, socioeconomic status (Bradley & Corwin, 2002) and learning disabilities (Bender, 2008). Several researchers have suggested examination of STEM integration in combination with other factors for learning (Maltese, et. al., 2014; Stone, 2011).

In order to prepare agriculture students to acquire critical science, technology, education, and mathematics skills, research must be conducted into the methods by which agricultural education can best fill their needs. Cognitive sequencing may play an important role in allowing students to grasp abstract concepts as applied in a contextual setting (Garlick, 2010; Marzano, et. al., 2001; Reigeluth, 1983). This research was conducted to fill the gap in the knowledge base by analyzing cognitive sequencing in STEM education concepts through the pedagogical approach of ELT, allowing for the most effective sequences for students based on other educational factors to be utilized and agricultural education students to have access to the most efficacious methods with regard to STEM integration. The following chapter will outline the framework for the study in relation to relevant literature.

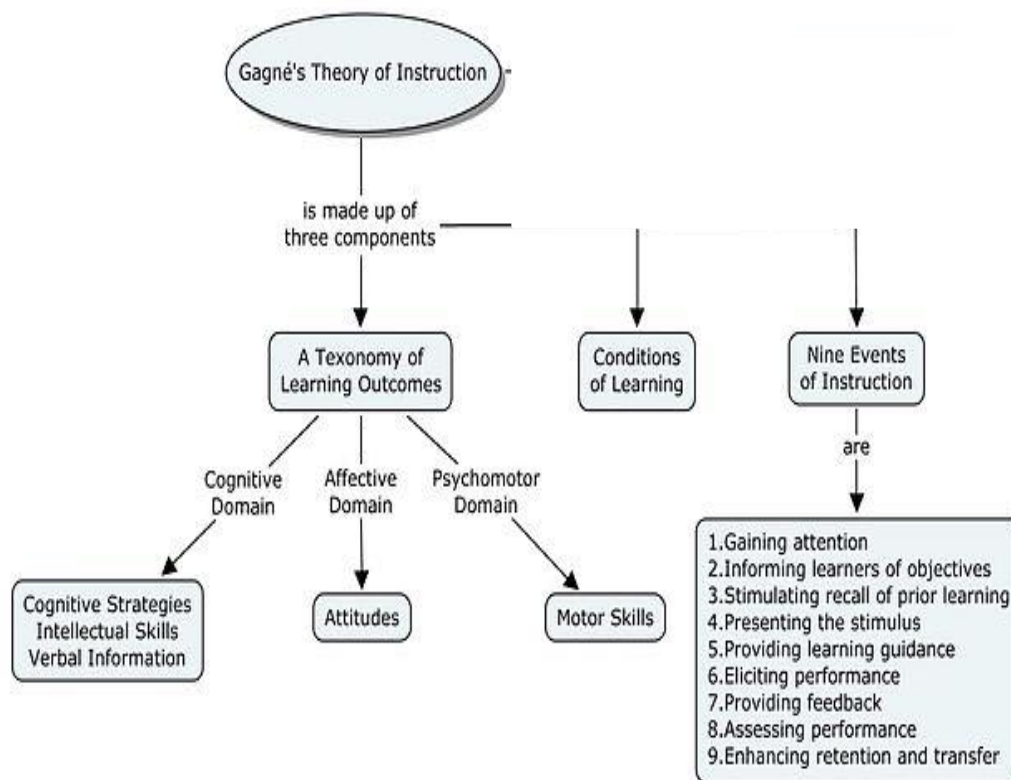
## CHAPTER II

### REVIEW OF LITERATURE

The exploration of any topic is best facilitated by a comprehensive investigation into research that provides background information and can serve as a basis for making study related decisions (Fraenkel, Wallen, & Hyun, 2012). The topic of determining the influence of cognitive sequencing for STEM concepts in agricultural education requires a review of literature related to STEM education, factors that affect learning in secondary education, cognitive sequencing of instruction, experiential learning, and the relationship between experiential learning and cognitive sequencing. This chapter provides an examination of the conceptual framework for the study, along with an overview of relevant literature.

#### **Conceptual Framework**

This study was based on a conceptual framework rooted in both Gagne's (1965) theory of instruction and Kolb's (1984) experiential learning theory. Gagne's (1965) theory of instruction accounts for an independent analysis of student, school and teacher, and instructional factors which may impact student learning. This model was developed by Gagne to give a complete overview of the instructional process. One of the most relevant portions of the model is Gagne's nine events of instruction, which Gagne (1965) described as the essential components for every instructional lesson. This theory is widely accepted as a complete system for addressing both the intent and specific actions that should be present in delivering information to students (Driscoll, 2004; Reigeluth, 1983). Gagne's theory is shown in Figure 1.



*Figure 1.* Gagne’s (1965) theory of instruction. Adapted from Driscoll (2004).

The conceptual framework for this study was influenced by Kolb’s experiential learning theory as the method for presenting the stimulus to students. Kolb’s model, as shown in Figure 2, is a “dynamic view of learning based on a learning cycle driven by the resolution of the dual dialectics of action/reflection and experience/abstraction” (Kolb, 2015, pp. 50-51). This model shows the cyclical process of learning as a relationship between the four modes of active experimentation (AE), concrete experience (CE), reflective observation (RO) and abstract conceptualization (AC) (Kolb, 1984, 2015).

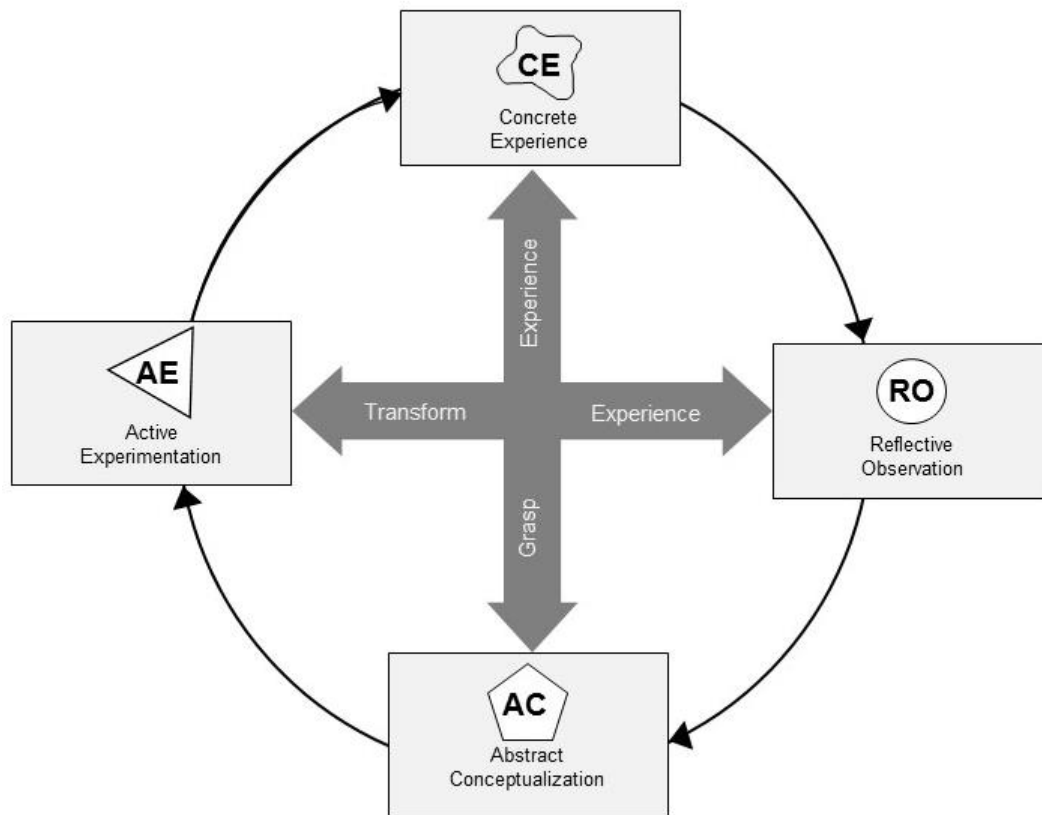
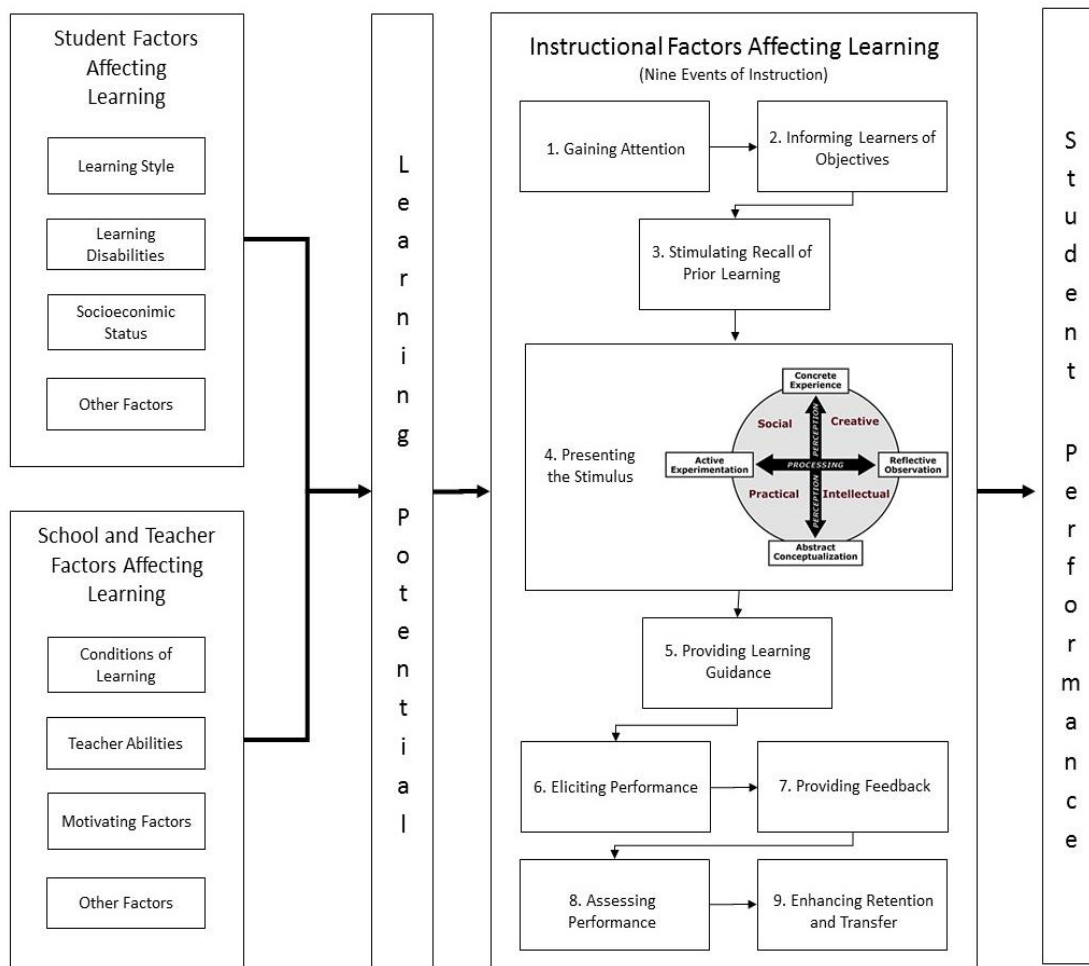


Figure 2. Kolb's (1984, 2015) experiential learning cycle. Reprinted from *Experiential Learning: Experience as the Source of Learning and Development* (51), By D. A. Kolb, 2015, Upper Saddle River, NJ: Pearson Education, Inc. Copyright D. A. Kolb. Reprinted with permission.

Both Gagne (1965), and Kolb (1984) examined the processes required for learning. Gagne's approach took into consideration the external factors related to learning outcome types and the conditions of learning, while Kolb's (1984) model looks specifically at the learning process. Using Gagne (1965) as a model for delivering instruction in combination with the use of Kolb's experiential learning cycle (1984) as the pedagogical foundation for presenting information to students led to the development of the conceptual model for this study.

The resulting conceptual model for this study is shown in Figure 3. The model relies on Gagne’s (1965) theory of instruction to guide instructional factors affecting learning. Experiential learning theory, as outlined by Kolb in 2015, was used as the theory guiding instruction for presenting the stimulus to students, with lessons accounting for all four of Kolb’s learning modes.



*Figure 3.* Conceptual model of student learning. Based on Gagne’s (1965) nine events of instruction and Kolb’s (1984, 2015) experiential learning theory.

Through this model, student performance was tested using experimental curricula developed to standardize the events of instruction as outlined by Gagne (1965), manipulating only the cognitive sequence with which information was presented. Resulting changes in learning between dependent measures were examined in relation to student factors affecting learning or manipulation of cognitive sequence.

### **STEM Education**

Science, Technology, Engineering, and Mathematics (STEM) are concepts that have been included in traditional instruction for many years (Maltese, et. al., 2014). The President's Council of Advisors on Science and Technology (PCAST, 2010) stated that the importance of STEM education is that it "will generate the inventors of future products and industries, train the STEM-skilled workers for these developments, and allow citizens to make informed choices in an increasingly technological world" (PCAST, 2010, p. 109). In order to understand the role of STEM education in relation to this study, an examination was made into the origin of STEM education and the current state of STEM education, both globally and in the United States. In addition, information was synthesized related to STEM education in Career and Technical Education as a whole and specifically to agricultural education.

#### *Origin and Current Status of STEM Education*

Formal education in the United States has always included components related to the areas of STEM education. Early colonial schools included instruction in the classical subjects of mathematics, and the first high schools included curriculum in astronomy and physics. Although these concepts have always been a part of the educational landscape



in America, the emphasis and modes of instruction for STEM concepts have evolved through the last century.

In the early 1960's, partially in response to the launch of Sputnik by the Russian government, the climate of education in America took a dramatic turn towards focused instruction in all STEM concepts (Kuenzi, 2008). Educational funding increased by 200% by the year 1970, with most of the new funds being earmarked for programs related to closing the achievement gap between the United States and other developed nations (Maltese, et. al., 2014). Agricultural education was not immune to this educational overhaul. The Vocational Education Act of 1963 created new mandates for CTE, including agricultural education, which included expanding the scope of curriculum from merely vocational in nature, to incorporate more academic areas (Maltese, et. al., 2014; Smith & Rayfield, 2015).

Duggar's (2000) examination of the origin of early STEM education revealed that the term "STEM Education" emerged as a product of the National Science Foundation (NSF) at the beginning of the 21<sup>st</sup> century. Through curriculum projects in the 1990s four subject areas emerged as essential for student success in the global economy. The term initially had the four content areas arranged in the term "SMET"; upon concerns that the term had too close of an association with the word "smut", the content areas were rearranged and the terminology was re-launched arranged as STEM (Duggar, 2000).

Globally, almost every country has examined the importance of integrating STEM concepts in formal education (Freeman, Marginson, & Tyler, 2014). STEM

education in the United States is an important factor driving educational reform. Nearly 91% of American adults feel as though science and technology education will yield opportunities for future generations, and over 60% believe current math and science education is inadequate (National Science Foundation, 2012; Maltese, et. al., 2014). The last three major governmentally driven mandates have contained verbiage related to the integration of science, technology, engineering, and mathematics in formal assessments of school performance (Maltese, et. al., 2014). The increased focus on STEM education is paired with a lack of information on how to most effectively teach these principles (Stone, 2007).

Some disagreement exists as to whether or not a STEM graduate shortage exists (Kuenzi, 2008; Metcalf, 2010). While the data on the number of STEM graduates is often questioned, industry concerns lead many researchers to conclude there is a critical level of decline in quality STEM graduates (Ashby, 2006; Maltese, et. al, 2014; Wang, 2013).

There are several suggested causes for the overall decline in STEM education which have been examined, including lack of quality high school preparation (Ashby, 2006), poor teacher quality (Degenhart, 2007; Kuenzi, 2008), and gender inequality in recruitment (Heilbronner, 2012). A 25 year longitudinal study of STEM professionals examined the impact of pre-college STEM exposure on STEM career success, leading to the conclusion that secondary exposure leads to higher levels of professional success (Wai, Lubinski, Steiger, 2010).

Governmental agencies have spent billions of dollars funding research in STEM education, with very little tangible evidence to show for their investment (Maltese, et. al., 2014; Stone, 2007). Maltese, et. al. (2014) surmised that, “at the federal level, support for STEM is one issue that generally remains above partisan politics, but differences surface in the discussion of how improvements should be made implemented, and funded” (p. 108). Challenges in initiating change in STEM education in the United States include the lack of unified control over STEM initiatives, conflicting views of direction for STEM research, and lack of knowledge about effective STEM practices (Maltese, et. al., 2014).

Research on STEM education has led to few practical suggestions for improving the quantity or quality of post-secondary students in STEM fields (Ashby, 2006; Maltese, et. al., 2014). In late 2013, a joint report from both the National Science Foundation and the Department of Education highlighted five suggestions for reaching their target of producing one million additional STEM graduates by 2020. Among these suggestions was to “provide more opportunities for hand-on, real-world STEM activities at the secondary level” (Ferrini-Mundy, 2013). It is not only the educational system which is examining methods to improve STEM education. Several large corporations have undertaken their own STEM education projects in an effort to instruct their own workforce, although no effective model has been developed by corporations at this point (Maltese, et. al., 2014).

Dugger (2010) stated that there are many different methods for delivering STEM content, stating “more work needs to be done that probes into which model or strategy

works best” (p. 5). With all of the differing opinions regarding STEM education, one universal truth remains “effective STEM education is vital for the future success of students” (Stohlmann, et. al., 2012).

### *STEM Education in Career and Technical Education*

Career and Technical Education (CTE) courses have been seen as a potential platform for the integration of STEM concepts (Stone, 2007, 2011). Historically, CTE courses have been taught with vocational training in mind. The shift toward an academic focus for CTE in the 1970s put added pressure on teachers and administrators to increase the core academic components of these courses (Stone, 2010). Stone (2010) analyzed this increasing pressure and concluded that models integrating STEM concepts into CTE courses allow CTE content areas to serve as the context for traditional academic concepts. He posited that “STEM-focused education can be incorporated into any CTE delivery system, program, or curricular or pedagogical approach within CTE” (Stone, 2011, p. 13)

CTE courses have been seen as an important factor in STEM learning for students, as they allow the application of abstract STEM concepts within the context of a vocational setting. Students who might struggle with these concepts may have increased understanding when given a concrete application for the abstractions (Garlick, 2010; Sousa, 2011; Stone, 2011; Pearson, Young, & Richardson, 2013).

One of the most well received suggestions for a model of STEM education which would be effective was presented by Berry, Chalmers, and Chandra (2012) at the Second International STEM in Education Conference. They outlined a model which relied on a

shared learning context as the application basis for instructing STEM concepts. They posited that the shared context “provides a focus to integrate learning and make it more meaningful to students” (p. 229). This shared context approach is much like what happens when STEM concepts are applied in a CTE course (Pearson, 2015).

Contextual learning is not new to CTE or agricultural education. Furner and Kumar (2007) stated that “integrated curriculum provides opportunities for more relevant, less fragmented, and more stimulating experiences for learners” (p. 186). Shinn, et. al. (2003) examined the role of agricultural education courses and career and technical education courses as important links in bridging the gap between the known and unknown through contextualized learning.

Researchers believe that the current nature of STEM education in the United States allows for integration of almost all STEM concepts into CTE courses (Pearson, Park, Sawyer, Samantaria, van der Mandele, Keene, & Taylor, 2010; Stone, 2011). CTE teachers, including agricultural educators, have a variety of professional development opportunities related to combining their curriculum with STEM concepts. Curriculum projects on federal, state, and local levels have focused on using these courses to teach abstract STEM concepts (Pearson, Young, & Richardson, 2013; Stone, 2007).

Although there is limited research on the impact of STEM-related curricula in CTE courses, the initial testing of CTE courses as a potential platform for delivering STEM concepts has yielded promising results. The Math-in-CTE initiative was developed through the National Research Center for Career and Technical Education (NRCCTE) to look at student mathematics performance when mathematics concepts

were delivered through the context of CTE classes (Stone, Alfeld, & Pearson, 2008). Researchers developed mathematics enhanced curriculum and instructed CTE teachers in the best practices for using the curriculum with input from stakeholders including teachers, parents, mathematics experts, and educational psychologists. The initial study included more than 3,000 students and 200 teachers in nine states. Not only did they find that students had greater performance and retention on mathematics concept exams after completing the curriculum, but they also found more than 73% of teachers continued to voluntarily use the curriculum materials after the study was completed (Stone, et. al., 2008). Longitudinal studies are still underway.

A similar Science-in-CTE program is being conducted through the NRCCTE. The pilot stages of this project yielded similar results to the math-in-CTE initiative. The pilot stage was completed at two sites, one in agricultural education and one in health sciences, and showed promising results for a full scale investigation (Pearson, 2015). Funding is secured to allow for a broader investigation of this program to examine if science infusion will yield results similar to the Math-in-CTE program (Pearson, 2015; Pearson, Young, & Richardson, 2013).

### *STEM Education in Agricultural Education*

Agricultural education has been closely tied to STEM education in the United States for the last 15 years. Research in STEM related to agricultural education has focused primarily on teacher perceptions, success of integration, and barriers to student STEM learning. A 2014 study was conducted to gather the overall perceptions of all four components of STEM education in agricultural education (Smith, McKim, &

Rayfield, 2014). The findings revealed that agriculture teacher ratings of the importance of integrating STEM concepts were high, supporting the notion that agriculture teachers are aware of shifts in educational structure mandating integration STEM concepts (Myers & Dyer, 2004; Smith, et. al., 2014).

Stubbs and Myers (2015) conducted a case study to comprehensively examine STEM education perceptions and efforts in three typical Florida high schools with school-based agricultural education (SBAE) programs. They found all three programs were teaching students about a variety of STEM disciplines and careers. Their findings include an acknowledgement of interdisciplinary STEM curriculum as an essential component of secondary agriculture courses, and the requirement of high levels of STEM knowledge for agriculture teachers to maintain a quality program (Stubbs & Myers, 2015).

The four individual concepts of STEM have also been investigated in agricultural education. Many studies have been conducted to investigate science as a topic of interest in agricultural education courses (Boone, Gartin, Boone, & Hughes, 2006; Brister & Swortzel, 2009; Clark, et al., 2012; Conroy, Dailey, & Shelley-Tolbert, 2000; Haynes, Robinson, Edwards, & Key, 2012; Johnson, 1996; Myers & Thompson, 2006; Myers & Washburn, 2008; Ricketts, Duncan, & Peake, 2006; Scales, Terry, & Torres, 2009; Thompson & Balschweid, 1999; Thompson & Balschweid, 2000; Thoron & Myers; 2012a, 2012b; Warnick, Thompson, & Gummer, 2004). The findings highlighted by those conducting research on science in agricultural education shed light on a close tie between agricultural education and many science concepts.

With the exception of biotechnology, which is widely considered a science concept (Pisano, 2006), minimal research has been conducted related to integration of technology in agriculture courses. Dexter, Doering, and Ridel (2006) proposed models for integrating technology content in high school agriculture courses. The study was limited to curriculum development, rather than teacher perceptions and beliefs. A review of available literature yielded no obvious current research related to agriculture teachers' perceptions or efficacy related to integrating engineering within secondary agriculture courses.

Parr, Edwards, and Leising (2006) found students who engaged in a math integrated agricultural power and technology class scored higher on a postsecondary math placement test. Although many studies point to agricultural education as an effective platform for STEM delivery, not all agricultural education STEM integrations have yielded successful results. A 2013 study by Clark revealed no change in student scores when mathematics concepts were integrated in a high school animal science course. These mixed results warrant additional research to determine the true impact of math integration in agricultural education and the instructional methods which may differ in these studies, which could have an impact on the outcome.

#### *Use of Science as Basis for Study*

While agriculture teachers feel as though all four of the STEM areas are important to agricultural education, much more research has been tied to the realm of science than the other three areas, (Smith, et. al., 2014). Shadish, Cook, and Campbell (2002) noted the importance of rooting causal research in sound theories and bodies of



established research. Using science as the STEM concept for this study allowed appropriate background research with which to frame this study and relate to the findings.

Science is arguably the STEM field most closely tied to agriculture. The U.S. Department of Education report on STEM majors highlighted that of agricultural science majors obtaining a bachelor's degree, 71.1% earned their degree in biological sciences, making science by far the most sought after STEM field for post-secondary agriculture students (US Dept of Education NCES 2009-161).

There have been several studies conducted to determine the level of success for integration of science concepts in agricultural education classrooms. Results of these studies highlighted the notion that agriculture teachers believe agriculture is an effective delivery method for science (Brister & Swortzel, 2009), and agriculture teachers are confident in their ability to integrate science concepts (Scales, Terry & Torres, 2009; Thompson & Balschweid, 2000). Teacher perceptions of content are important. Knezek, Christensen, and Tyler-Wood (2011) examined teacher perceptions of science concepts and student performance on science assessments. They concluded "a teacher's attitude toward science can impact teaching methodologies, and subsequently, the amount of time spent in teaching science content" (p. 94). Additional research has suggested the importance of teacher efficacy on successful teaching (Bandura, 1986; Stohlman, Moore, & Roehrig, 2012; Tschannen-Moran, & Hoy, 2001). By focusing on science, an area of high agriculture teacher self-efficacy (Smith, Rayfield, McKim, 2015), this study was

designed in an attempt to prevent issues which can arise when teachers are not efficacious in the content of their teaching.

Context-based learning was another reason to tie this study specifically to science. The importance of context-based learning is perhaps best stated by Bennett, Lubben, and Hogarth (2007), “context-based scientific courses motivate students and help them feel more positive about science by helping them see the importance of what they are studying” (p. 248). Results related to science concepts in agricultural education substantiate this definition, as researchers have concluded that agricultural classes can be more effective at increasing student science scores than standalone science courses (Clark, Parr, Peake, & Flanders. 2013; Myers & Dyer, 2004; Ricketts, Duncan, & Peake, 2006).

Agricultural education has a long history in utilizing concepts of experiential learning theory (Roberts, 2006). Specifically related to science, experts have suggested that using experiential learning may be the best pedagogical approach for teaching abstract concepts. The national core science standards state that when instructing science concepts “educators should actively engage students so they learn by doing” (p. 128, Maletese, et. al., 2014). The Science-in-CTE study was framed around a conceptual model that included components of experiential learning theory (Pearson, et. al., 2013), although the study was not fully framed using ELT. Placing STEM learning in agricultural education within the frame of ELT provides a means for interpreting results related to individual student preferences in the ELT model.

The volume of work conducted in the integration of science in agricultural education has laid the groundwork for this study. An examination of these studies highlight agricultural education as a logical platform for instruction in core science concepts. The background work in science was an important first step in expanding agricultural education STEM research into a quasi-experimental design. Future expansion of this study into the other three content areas of STEM education would be the next step in pursuing cognitive sequencing as a line of inquiry for agricultural education, but would be most successfully attempted only after the increase in the knowledge base related to the role of technology, engineering, and mathematics in agricultural education is increased.

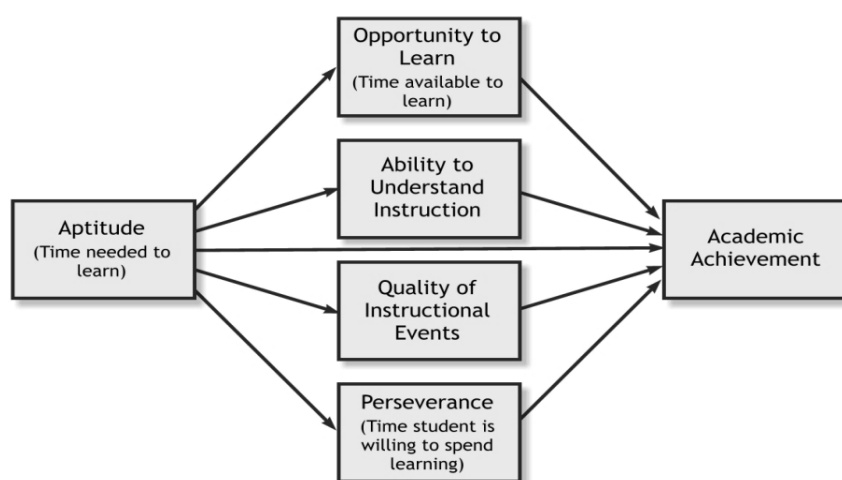
### **Factors Affecting Learning**

According to Sousa (2010), there are nearly innumerable factors that can affect human capacity for learning. It would be almost impossible to conduct causal research in social science that would account for all factors of each individual (Meyers, et. al., 2013; Sousa, 2010; Zull, 2002). Although it is not within the scope or intent of this study to examine all factors related to learning, there are several learning factors shown to impact student learning which could be logistically and practically classified in the course of this research. This section will first give an overview of the research related to determining the factors which may influence student learning. Following the overview, a complete examination of the factors which serve as three of the independent variables for this quasi-experiment will be analyzed. These factors of interest are learning style, socioeconomic status, and learning disabilities.

### *Overview of Factors Which May Influence Learning*

Cognitive scientists have drawn the conclusion that the learning process is individual, and likely influenced by both individual student and school-based factors (Huitt, 2003). Determining those factors has been a line of inquiry for educational researchers for decades. Common threads of influence in foundational works include student factors of motivation, ability, and home environment, and school-based factors related to teacher ability and school climate (Carroll, 1963; Gagne, 1965). The foundational works have been substantiated by researchers continuing the examination of factors related to learning (Darling-Hammond & Bransford, 2005; Silins & Mumford, 2002; Stringer, Christensen & Baldwin, 2009)

One of the pioneers in suggesting factors contributing to student learning was John Carroll, who outlined his model for school learning in 1963. Carroll's model is shown in Figure 4.



*Figure 4.* Carroll's (1963) model of school learning. Reprinted from Carroll (1989).

Carroll (1963) proposed aptitude as the time needed for individual students to learn a specific task, and listed opportunity to learn, perseverance, quality of instruction, and ability to understand instruction as factors which would impact student achievement, as shown in Figure 4.. This model, shown in Figure 4 has served as a foundation for other researchers to build upon as they examine factors which influence learning in a school setting.

Gagne (1965) proposed an expanded model, and stated for learning to occur, specific conditions must be present. These include a motivated learner and a recall of the component knowledge leading to the new concept. Gagne (1965) went on to address the basis for instructional design in the outcome of learning, suggesting instruction should factor in the desired behavior exhibited by the learner after instruction. To address learning outcomes and the conditions of learning, Gagne proposed “nine events of instruction”. The nine steps that Gagne (1965) proposed for effective instruction are: gaining attention, informing learners of objectives, stimulating recall of prior learning, presenting the stimulus, providing learning guidance, eliciting performance, providing feedback, assessing performance, and enhancing retention and transfer. Gagne’s theory led him to conclude that these nine events were the critical format for any instruction (Gagne, 1965).

Squires, Huitt, and Segars (1981), refined a holistic model in which school leadership, supervision, and schoolwide norms, combined with teacher and student behaviors, were set forth as the factors contributing to overall student success. Several other educational psychologists followed suit, and have outlined models for learning that

include the influences of both the school and teacher, along with individual student factors on student learning (Fraser, 1987).

In agricultural education, variables of interest for student learning were examined by Myers and Osborne in 2005, as they sought to analyze areas for strengthening agricultural education research. Their findings were in line with many of the factors identified in research on factors involved in broader educational research (Hattie & Anderman, 2013). Within this conceptual model, they suggested variables of interest in student, context, and teacher categories (Myers & Osborne, 2005). Student variables of interest included demographic information, thinking skills, learning style, and experience (Myers & Osborne, 2005). Context variables included school demographics, agriscience program, teaching resources, school climate, community, and school curriculum. Finally, Myers and Osborne (2005) suggested the teacher variables of interest included demographic information, science process skill, thinking skills, learning style, experience, and preparation.

### *School and Teacher Factors Affecting Learning*

Both school and teacher factors have been highlighted as aspects that play a role in student learning. Frequently noted in the literature are the influences of school climate and teacher effectiveness (Huitt, 2003; Stringer, et. al., 2009).

### **School Climate**

Defining the construct of school climate has been heavily researched as educational psychologists searched for a variable that might encompass the impact of school environmental factors on student motivation, engagement and achievement

(Anderson, 1982). Although many different interpretations of the terminology “school climate” exist, a comprehensive definition was compiled in 2009 by Cohen, McCabe, Mitchelli, and Pickeral. They stated:

School climate refers to the quality and character of school life. School climate is based on patterns of people’s experiences of school life and reflects norms, goals, values, interpersonal relationships, teaching and learning practices, and organizational structures. A sustainable, positive school climate fosters youth development and learning necessary for a productive, contributive, and satisfying life in a democratic society (p. 182).

Examining this definition gives a partial explanation of why the construct would be difficult to measure in the context of this study. School climate has been noted as a factor which may play a large role in student achievement (Anderson, 1982; Stringer, et. al., 2009).

School climate is different at every school (Anderson, 1982; Cohen, et. al., 2009). Making this factor even more difficult to study, school climate is influenced by so many facets of a school that climate is different at every school, every year, and may even be different every day (Cohen, et. al., 2009). School climate is a factor often overlooked in teacher preparation, perhaps due to the highly individualized nature of climates in each school (Darling-Hammond & Bransford, 2007).

The complex nature of school climate as an ever-changing variable makes it nearly impossible to quantify (Anderson, 1982; Cohen, et. al., 2009). This study was

conducted at schools with vastly different school climates, in order to examine the outcome of STEM learning in a variety of school climate settings.

### **Teacher Effectiveness**

It would seem intuitive for teacher effectiveness to play an obvious role as a factor affecting student learning. This concept is as varied between teachers as school climate is between individual schools. Teacher effectiveness has been studied as an important factor related to student achievement (Darling-Hammond & Bransford, 2005; Squires, et. al., 1981; Stringer, et. al., 2009).

Rosenshine and Furst (1971) conducted a seminal meta-analysis of the factors most often associated with quality teaching. Their examination yielded eleven different characteristics of effective teachers. The analysis of the variables led them to conclude “the best results were obtained on the first five variables” (Rosenshine & Furst, 1971, p. 42). These five variables are described in Table 1.

Table 1

<i>Selected Characteristics of Effective Teachers (Rosenshine &amp; Furst, 1971)</i>	
Characteristic	Description
Clarity	Effective teachers can clearly communicate abstract concepts
Variability	The ability to use variety in teaching methods, learning modes, and delivery strategies
Enthusiasm	Excitement about students, subject, and the profession of teaching
Task-Oriented and/or Business-like Behaviors	Exhibits business-like behaviors
Student Opportunity to Learn Criterion Materials	Gears instruction and assessments to predefined learning outcomes



Feldman (1976) described the characteristics of clarity and the ability to stimulate student interest as factors important for effective teaching. In addition, his examination yielded subject matter knowledge, organization and preparation for class, and enthusiasm as characteristics teachers should embody to be successful. Reid and Johnstone (1999) analyzed effective teaching behaviors and developed a list which included approachability, clarity, depth of knowledge, interaction, interest, and organization. Other examinations of effective teaching factors have substantiated the claims related to the influence of ability to interact with students, content knowledge, and ability to employ instructional strategies on teacher effectiveness (Young & Shaw, 1999).

The factors of effective agricultural educators have been examined in an effort to provide insight and guidance for teacher educators and those seeking employment in the profession (Newcomb, McCracken, Warmbrod, & Whittington, 2004; Miller, Kahler, & Rheault, 1989; Roberts & Dyer, 2004; Talbert, Vaughn, Croom, & Lee, 2014). From these examinations, it can be concluded that effective agricultural educators must possess the characteristics of effective regular classroom teachers, with an extension into the other two circles of the agricultural education model. Roberts and Dyer (2004) conducted a Delphi study allowing experts in agricultural education to weigh in on the factors of effective teaching as they relate specifically to agricultural education. Their findings led them to conclude “being an effective agriculture teacher goes beyond classroom teaching” (p. 94).

Quality teaching has been suggested as a possible factor in the lack of qualified STEM graduates at the postsecondary level (Ashby, 2006; Maltese, et. al., 2014, Wang, 2013). Once again, due to the complex nature of this variable, experimental curricula were delivered by three different teachers, with full understanding that each of the teachers have a different level of effectiveness in many different aspects of instruction. This quasi-experiment was conducted with full acknowledgement of the role teacher effectiveness may have played as a limitation to this study.

### **Role of School and Teacher Factors in This Study**

Each school has a unique set of factors that can impact student learning, as can each individual teacher within a school (Darling-Hammond & Bransford, 2005). It was not the intent of this study to completely control for those factors related to learning. Rather, the intent of this study was to conduct a quasi-experiment in a variety of school locations and with numerous teachers in order to substantiate findings which might extend to a variety of teaching settings. Therefore, the role of school and teacher factors were knowingly acknowledged as potential confounding variables which were limitations of this study. According to Ary, Jacobs, and Sorenson (2010), there is value in conducting quasi-experimental research in real classroom settings as it provides insight into the treatment effects in actual educational settings.

### *Student Factors Contributing to Learning*

Researchers who have conducted research on student learning universally agree that each student is unique in the way they grasp and transform learning. The concept of differentiated instruction, as examined by Tomlinson (2001, 2014) is based on the

premise that each student is unique in their educational requirements and should therefore be instructed in a manner which best meets their individual needs. This definition presents a large challenge for modern education: How can all students be taught in classroom units using the methods which are most effective for individualized learning?

As researchers have tackled this question, several factors emerged as potential classifying variables which could account for a portion of individual learning aptitude. Among these factors are learning style (Brokaw & Merz, 2000; Claxton & Murrell, 1987; Coffield, Moseley, Hall, & Ecclestone, 2004a, 2004b; Duff, 2004; Dunn and Dunn, 1989; Felder & Silverman, 1988; Fleming, 2001; Gregorc, 1979; Kolb, 1985, 2015; Tomlinson, 1999), socioeconomic status (Bradley & Corwin, 2002; Hoover, Bassler, & Brissie, 1987; Sirin, 2005; White, 1982), and ability to understand instruction (Bender, 2007, 2008; Carroll, 1963; Hampton & Mason, 2003).

In this section, the factors classified as independent variables for this study (learning style, socioeconomic status, and learning disabilities) will be examined as they relate to student performance.

### **Learning Style**

From the examination of many different individual factors affecting student learning, the concept of learning styles emerged. Learning styles are assessed by analyzing, comparing, and contrasting student preferences in relation to several different factors affecting learning (Sousa, 2011). Individual student learning style has been examined in relation to learning by many researchers (Brokaw & Merz, 2000; Claxton &

Murrell, 1987; Coffield, Moseley, Hall, & Ecclestone, 2004a, 2004b; Duff, 2004; Dunn and Dunn, 1989; Felder & Silverman, 1988; Fleming, 2001; Gregorc, 1979; Kolb, 1985, 2015; Tomlinson, 1999). Some researchers have concluded that learning style cannot be conclusively used as an assessment of overall learning capabilities of an individual (Pashler, McDaniel, Rohrer, & Bjork, 2008). However, Kolb & Kolb (2005, 2009) posit that learning style is an important indicator of preference for learning, and subsequent engagement in the learning process. Sousa (2011) discussed the varying acceptance of learning styles within academia and neuroscience and said that, despite the argument on how to use learning styles, “there is little argument that people have various internal and external preferences when they are learning” (p. 59). Examining the role of learning style in student performance depends greatly on which instrument is being used to assess individual style. Each learning style instrument takes a different approach to differentiating between personal characteristics and has different separation of factors related to learning and retention.

Hawk and Shah (2007) examined the use of learning style instruments to enhance student learning. They outline and describe six common learning style inventories which can be used to assess student learning style. These descriptions are found in Table 2.

Due to the close tie between *Kolb’s Learning Style Inventory (KLSI)* and Kolb’s experiential learning theory, the decision was made to use this instrument as an assessment of student learning style within this study. The *KLSI* is comprised of an

assessment of respondent preferences on the dual dialectics of grasping and transforming experience (Kolb, 1984, 2015). The instrument is discussed in detail in Chapter Three.

Table 2

*Descriptions of Six Common Instruments for Assessing Learning Style (Hawk & Shah, 2007)*

Instrument	Description
Kolb Learning Style Inventory	Compares differences in learning based on how much emphasis is placed on the four modes of abstract conceptualism, concrete experience, reflective observation, and active experimentation (Kolb, 1984)
Gregorc Learning Style Delineator	Analyzes observable behaviors to determine the mediation abilities of individuals and how they relate to the world (Gregorc, 1979)
Felder and Silverman Learning Style Assessment	Characterizes individual strengths and preferences for taking in and processing information (Felder & Silverman, 1988)
VARK Questionnaire	Characterizes preferences for gathering, organizing, and comprehending information (Fleming, 2001)
Dunn and Dunn Learning Styles Inventory	Examines methods for concentrating, processing, internalizing, and retaining new and complex information (Dunn & Dunn, 1989)
Revised Approaches to Studying Inventory (RASI)	Composite analysis of cognitive, affective, and psychological factors that examine how an individual interacts with the learning environment (Duff, 2004)

Identifying preferences for grasping new experiences through apprehension as opposed to comprehension provides important information about how cognitive sequencing of information might play a role in student learning. It would stand to reason that students who have a preference for grasping information through apprehension

could perform higher on units with STEM integration when the concrete experience was presented as the initial point in the learning cycle. By contrast, students who show a preference for grasping experience through comprehension may grasp STEM concepts more readily when the abstract conceptualization stimulus was presented as the beginning point for the learning cycle.

### **Socioeconomic Status**

Socioeconomic status (SES) has repeatedly manifested as a factor in student learning (Hoover-Dempsey, Bassler, & Brissie, 1987; Sirin, 2005; White, 1982). Bradley and Corwyn (2002) posit that “for over 70 years findings on the relationship between SES and intellectual/ academic competence has accumulated” (p. 375). This factor has been attributed to a large amount of the variation in student school performance. White (1982) conducted a meta-analysis of research on SES and school performance, and attributed 5% of the variance in academic achievement to SES. In a 2005 replication of White’s (1982) meta-analysis, Sirin (2005) suggested that 5% of variance would be a very conservative estimate of the impact of SES on student achievement.

Researchers who have studied SES as a factor in learning have suggested numerous reasons low SES has correlated to lower student aptitude (Bumgarner & Brooks-Glenn (2013). One of these suggestions is parental earning as an indicator of low parental academic aptitude. Proponents of this concept (St. John, 1970; Skiba, Poloini-Staudinger, Simmons, Feggins-Azziz, & Chung, 2005) often view low SES as an indicator of a genetic predisposition to lower IQ and academic performance. Duncan

and Magnuson (2014) stressed the importance of adding “genetic influences to a long list of potentially important factors that deserve attention in studies that seek estimates of the causal effects of SES on children’s development” (p. 94). However, they cautioned that genetics alone could not be a possible factor to account for all of the differences in student performance based on SES, saying “the evidence suggests that something about SES, unrelated to genetic endowment, [is] responsible for the differential gains” (p. 94).

Other researchers point to the fact that often in low SES families, both parents spend extended time working, leaving less time for individual parental interaction with students in their pre-school years, allowing these students to fall behind due to their environment before they ever enter the school system (Hoover-Dempsey, et. al., 1987). Bornstein and Bradley (2014) examine this and said:

There is near universal agreement that higher SES children have access to more of the resources needed to support their positive development than do lower SES children. For young children, it is assumed that much of the influence of SES on development is mediated directly through what parents afford by the way of financial and human capital. As children age, SES increasingly operates through the social capital afforded by parents and through neighborhood-community connections. (p. 1)

Their assessment presents the underlying assumption of SES having an impact on student resources. Neiss and Rowe (2000) compared gains in verbal IQ between children adopted into families with both high and low SES classification. Their findings revealed

a difference in IQ gains which was significant between the two groups, suggesting a factor outside of genetics as influential for SES and student achievement.

There are many different methods for determining student SES. Bradley and Corwyn (2002) outline the importance of integrating as many factors contributing to student SES as possible, citing parental occupation, education level, and income as the most important factors to classify. One of the factors indicating SES which has been widely employed by educational researchers is qualification for the free and reduced lunch program (Harwell & LeBeau, 2010). This program provides students with access to the school nutrition program at low or no cost to students whose household income is below a specified level.

While there are concerns that using free and reduced lunch classification as an indicator of SES is not the most complete assessment of student overall SES (Harwell & LeBeau, 2010), it is perhaps the most accessible and efficient way to classify students as low SES (Skiba, Poloini-Staudinger, Simmons, Feggins-Azziz, & Chung, 2005). For this reason, the SES classification used in this study was student free/reduced lunch status.

### **Learning Disabilities**

The ability to learn is a factor of student learning referred to in almost all models examining student achievement (Bender; 2004). As all students are individuals, each has an individual aptitude and capacity for bringing in, storing, and retaining information (Sousa, 2011). Accounting for individual learning ability in education is essential within an examination of how students learn.



In the United States, legislation exists that provides accommodations and modifications to the instruction and assessment of students who are classified with a condition which inhibits their learning. The origin of learning disability classification can be traced to Public Law 94-142, The Education Act for All Handicapped Children Act of 1975 (EHA). This educational policy outlined the requirements for instruction related to students with learning disabilities, including: free appropriate public education for children three to 21 years old, protecting the rights of children with disabilities and their parents, Individualized Education Plans (IEPs), providing a least restrictive environment for learning. The legislation also provided provisions for federal funding to meet the aims of the new policy (Osborne & Russo, 2014). This legislation has been updated and revised to include more specific information related to how to ensure the needs of special education students in the country are met (Osborne & Russo, 2014).

The very definition of learning disability (LD) lends itself to the importance of using learning disability status as a factor in understanding student achievement. Bender (2008) defined a learning disability as “a condition giving rise to difficulties in acquiring knowledge and skills to the level expected of those of the same age, especially when not associated with a physical handicap” (p. 18). Although there are large differences in the types of learning disabilities classified by federal legislation, researchers have found that collectively, students classified with a LD have lower test performance and GPA than those without learning disabilities, even when the accommodations of an IEP are in place (Hampton & Mason, 2003).

One of the most common manifestations of learning disabilities is difficulty converting abstract knowledge into applied knowledge (Bender, 2004). This is an important factor for STEM education, as many of the concepts are incredibly abstract when presented without context (Stone, 2011). In STEM fields, there are known differences in the performance of students with learning disabilities on STEM assessments (Boaler, 1998; Kieran, 1992; Woodward & Montague, 2002). This examination has led researchers to conclude that there may be a large advantage to allowing students with learning disabilities to approach abstract concepts, like those in STEM education, through applied means (Furner & Kumar, 2007; Stone, 2011)

In addition, researchers have explained the importance of examining performance of students with learning disabilities within research studies. Bender (2008) outlined the importance of ensuring educational researchers are mindful of the ways in which students with learning disabilities learn content and perform on assessments. Bender (2007) also shared the critical need to provide LD students with differentiated instruction that allows them to experience education in the teaching strategy most closely aligning with their capacity for learning. The concept of cognitive sequencing is a way to differentiate instruction that could provide assistance for students with learning disabilities, especially related to presenting information using the cognitive sequence students prefer to grasp information in first (Woodward & Montague, 2002).

CTE courses are home to a disproportionate number of students with learning disabilities (Wagner, Newman, & Javitz, 2015). In a national study of more than 9,000

public high school students with learning disabilities, 96.0% had taken at least one CTE course during their high school tenure (Wagner, et. al., 2015). To further demonstrate the broad-scale involvement of LD students in CTE courses, the study revealed that CTE courses accounted for nearly one-fifth (19.7%) of all high school credits earned by LD students (Wagner, et. al., 2015). By comparison, CTE courses only accounted for 12.8% of the total credits earned by all high school students combined (Wagner, et. al., 2015).

The most accessible factor for classifying LD students is the presence of an IEP on file with the school (Bender, 2008). It is important to note that learning disabilities are varied, and that each level and type of LD has a different potential effect on student academic performance. The presence or absence of LD classification is not a perfect indicator of student academic ability, however, it can be useful in classifying students who typically need supplemental educational assistance, and therefore, have learning differences from their peers (Bender, 2004).

### **Cognitive Sequencing of Instruction**

At the core of cognitive science is a single defining truth; understanding a concept is the creation of a cognitive connection between a stimulus and stored abstractions in the mind (Garlick, 2010; Sousa, 2011). While cognitive psychologists and neuroscientists are still unraveling the biological science behind this phenomenon, there are certain concepts of learning that are well understood from both a psychological and cognitive science standpoint (Sousa, 2010).

Concepts relating to this study that are well-known in the field of cognitive learning and understanding include the importance of having a systematic presentation

of instruction for student learning, and the importance of presenting information in a logical manner that allows the brain to make connections to pre-existing knowledge (Sousa 2010, 2011; Zull, 2002). This section will briefly examine the role of both cognitive science and psychology as they are related to education, then examine the principles of grasping information through each platform. Information related to theories of instruction and cognitive sequencing will also be explored holistically and as they apply specifically to experiential learning theory and the objectives of this study.

### *Concepts Related to Grasping Information*

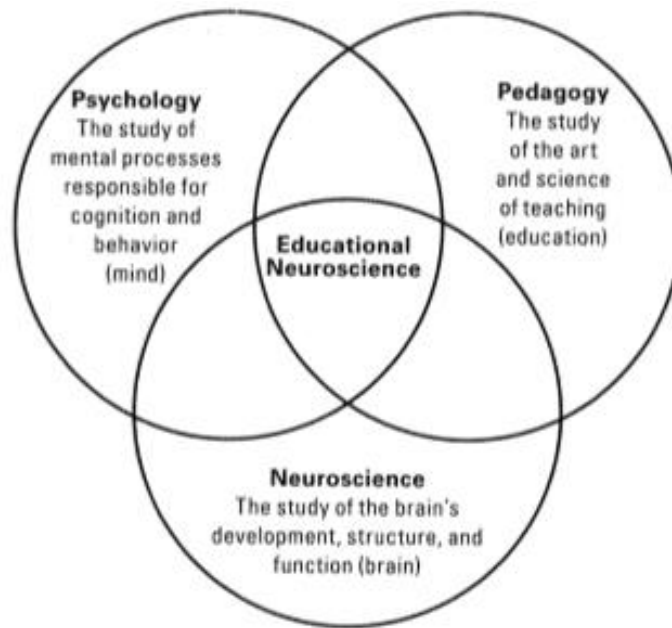
Prior to the last 30 years, many psychologists believed in the separation between the mind and the brain (Sousa, 2010, 2011; Zull, 2002). Advances in both the knowledge base and equipment used to examine how the brain works has led most experts to now believe in the concept of the mind and brain as one entity (Zull, 2002). Researchers now have a more complete understanding of how information is converted into knowledge, and are relying on neuroscientific principles more often as a source of information to guide student learning and development (Willis, 2010). Why is an understanding of neuroscience important to understanding education? David Sousa (2011) pointed out that:

Educators are not neuroscientists, but they are members of the only profession in which their job is to change the human brain every day. Therefore, the more they know about how it works, the more likely they are to be successful at changing it (p. 10)

This important tie between neuroscience and education has an uncanny relationship to the concepts of major educational theorists which emerged well before scientific abilities to examine neuroscience principles (Willis, 2010). Willis (2010) said:

It is striking how the accumulated scientific research since the early 1990s supports theories of learning from educational and psychological visionaries, such as William James, Lev Vygotsky, Jean, Piaget, John Dewey, Stephen Krashen, Howard Gardner, and others (p. 46).

These links can provide important insights into the relationships between a concept like cognitive sequencing as it relates to both the neuroscientific principles and psychological principles of understanding learning. It is important to note the role of the theorists mentioned by Willis (2010) on experiential learning theory. The relationships between psychology, pedagogy, and neuroscience, as discussed by Sousa (2010), are shown in Figure 5.



*Figure 5.* The interaction leading to educational neuroscience. Reprinted from Sousa, (2011).

The concept of learning is the contextualization of abstractions for the purpose of retention and application (Gagne, 1962). The manner with which information enters the brain's processing center and is transformed into memory has implications in both neuroscience and psychology (Sousa, 2010). From a neuroscience perspective, grasping information is related to the input of information through the senses, and the resulting physical and chemical changes which occur in the brain tissue as a result of the stimulus (Sousa, 2011).

Among the most important psychological principles for learning is the proposed difference between types of knowledge. The conversation about this concept was first introduced in the psychology arena by William James (1890). As James (1890) explained, one way of knowing involves concepts related to the tangible world. These

concepts rely on sensory inputs which are stored within the mind and not easily communicated. The second way of knowing involves the symbolic representation of concepts which can be easily communicated to others as abstract concepts. This type of knowledge is characterized by verbal analogies and descriptions which have transferability between the minds of different people (James, 1890; Kolb, 2015).

These two ways of knowing were echoed by Zull (2011) in the neuroscience field as he described the importance of being able to both gather information and transform the information into knowledge which could be communicated to others. Willis (2010) also examined grasping information and described the importance of the presentation order for new concepts saying “the brain evaluates new stimuli for clues that help connect incoming information with stored patterns, categories of data, or past experiences, thereby extending existing patterns with the new input” (p. 59).

The information from both neuroscience and philosophy regarding the importance of sequence on grasping information provided insight for this study, as causal research related to the topic of cognitive sequencing in both agricultural education and STEM fields were an apparent gap in the knowledge base.

### *Theories Related to Sequencing Instruction*

Determining the background related to sequencing instruction in STEM education required gathering information related to instructional theories holistically. Historically, there have been many instructional theories of note, developed by theorists who have conflicting views of the direction that educators should take in approaching the concepts of teaching and learning (Reigeluth, 2013). Many theories of instruction do

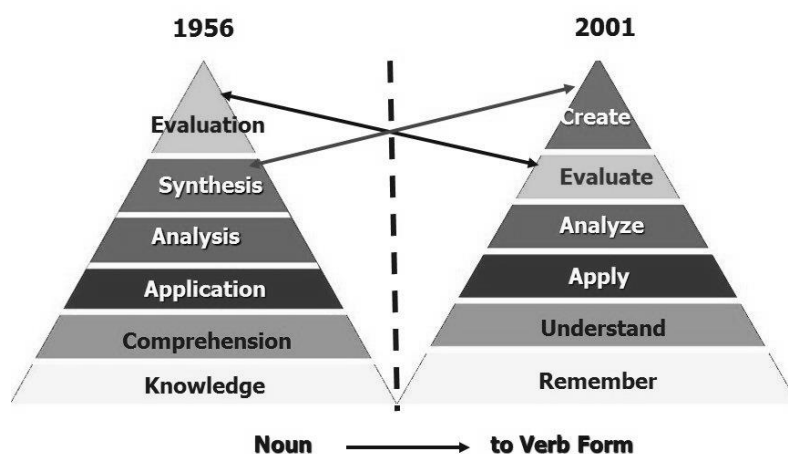
not propose a preferred order for sequential presentation of information, however, there are several which give specific outlines for the sequencing of information. The concepts of sequencing instruction are most commonly related to the sequencing of critical thinking skills or presenting information which builds from basic to more advanced concepts (Reigeluth, 2013).

Several prominent theorists have given their endorsement for instruction which is sequenced based on the complexity level of concepts. Of these theorists, most have advocated for a progression from surface level or more basic thinking skills to higher order thinking skills. Scandura (1983) posited that a method of instruction from less complex to more levels of thinking increases student understanding and cognition. Likewise, Bruner (1966) showed strong favor for what he called a “concept then application” order for sequencing thinking skills, which indicates he believed instruction beginning with abstract conceptualization and moving to concrete experience was preferable.

Bloom (1956) set forth a theory of instruction that was based on what he deemed the “taxonomy of learning outcomes.” His theory carefully examined the levels of cognition leading to student understanding. Bloom’s theory is rooted in the presentation of lower level thinking skills first, and progressively instructing students using higher levels of cognitive thinking skills. Anderson, Krathwohl, and Bloom (2001) adapted Bloom’s (1956) taxonomy to reflect new cognitive levels and updated terminology to allow for verb rather than noun usage and to match advances in educational research. A



comparison of the original taxonomy (Bloom, 1956) and the updated taxonomy (Anderson, et. al., 2001) is shown in Figure 6.



*Figure 6.* Comparison of Bloom’s (1956) taxonomy to Anderson et al. (2001) revision. Adapted from Anderson et al. (2001).

Norman Webb (1997) proposed a new four stage theory of instruction that was rooted in cognitive levels as well. Webb developed his four depth of knowledge levels while attempting to determine the level of alignment between the expectations and assessments of student performance in science and mathematics in 25 states (Webb, 1997). A thorough analysis of the alignment of the assessment and standards in these states led Webb (1997) to develop five criteria for aligning assessments and expectations. One of these five criteria was the “depth of knowledge consistency” (Webb, 1997, p15).

Webb explained the importance of his theory of depth of knowledge consistency by stating, “the depth of knowledge or the cognitive demands of what students are

expected to be able to do is related to the number and strength of the connections within and between mental networks" (Webb, 1997, p. 15). Through his evaluation on alignment, he outlined four levels for determining depth of knowledge (Webb, 1999). These levels are shown in Table 3.

Webb's depth of knowledge (DOK) levels allows educators to examine cognitive levels for both assessment and instruction. The assigning of both educational standards and assessments using DOK levels has reached educational systems across all content areas (Hess, Jones, Carlock, & Walkup, 2009).

Unlike Bloom and Webb, other theorists have been advocates for a sequence of instruction which begins with higher order thinking and progresses to surface thinking. Landa's (1983) algo-heuristic theory of instruction strongly suggests instructing students at the highest order first, and allowing them to work through the harder concepts to reveal the base knowledge.

Table 3

*Webb's Depth-of-knowledge (DOK) Levels (Webb, 1997, 1999)*

Level	Description
DOK-1 Recall & Reproduction:	Students can recall a fact, term, principle, concept, or can perform a routine procedure
DOK-2 Basic Application of Skills/Concepts:	Students can use information or conceptual knowledge, can select the appropriate procedures for a task, perform two or more steps with decision points along the way, solve routine problems, organize or display data, interpret or use simple graphs
DOK-3 Strategic Thinking:	Students can reason or develop a plan to approach a problem, employ decision-making and justification skills, solve abstract, complex, or non-routine problems
DOK-4 Extended Thinking	Students can perform investigations or apply concepts and skills to the real world that require time for research, problem-solving, and processing of multiple conditions of the problem, or perform non-routine manipulations across disciplines, content areas, or sources

The elaboration theory (Reigeluth, Merrill, Wilson, & Spiller, 1980) came to light in the early 1980s as a series of decisions about sequencing units of instruction in an entire course. Reigeluth (1983) explained that there are many decisions that go into the sequencing of instruction, stating “the issue, as with most instructional strategies is not whether it [sequencing units] makes a difference, but when it makes a difference” (p. 430). Reigeluth (1983) continued by proposing that sequencing of instructional units is important “when there is a strong relationship between the topics of the course” (p. 431).

It would stand to reason, within the confines of the elaboration theory that if cognitive sequencing is important in an entire course, sequencing within a unit of instruction would be equally important, as the topics within a single unit of instruction are highly related. These theories provide conflicting views of sequence for higher levels of thinking and abstract concepts, and highlight the importance of studying the effects of sequencing instruction in the context of STEM concepts in agricultural education.

### **Experiential Learning Theory**

Experiential learning theory is, according to David Kolb (2015), “the foundation for an approach to education and learning as a lifelong process that is soundly based in intellectual traditions of social psychology, philosophy, and cognitive psychology” (p. 3). This educational theory has been prominent in educational literature since the late 1970s, and continues to garner popularity as a framework for educational curriculum, philosophical discussions, and research (Kolb, 2015). This section will discuss the origins and background of experiential learning theory, the relationship between ELT

and the *KLSI* instrument, and the relationship of ELT to cognitive sequencing as examined through this study.

### *Learning from Experience*

Experiential learning theory is based on the premise that learning is a dynamic interaction between the learner, the methods through which information is gathered, and the methods by which information is processed in the mind (Kolb, 1984, 2015).

Experience as it relates to student learning and education is not a new concept. As early as Aristotle, the importance of humans relying on tangible knowledge to grasp abstract concepts was prevalent in educational philosophy (Cahn, 2011).

William James emerged in the late 1800s with proposals for education that relied on experiences (James, 1890). In fact, the concept of James' dual knowledge theory was derived in part from his examination of how information can be classified in the mind (James, 1890). Essentially, James outlined the principle that knowledge exists in two separate forms. The first type of knowledge, which James called "knowledge of acquaintance" is based on direct sensory input (sight, touch, sound) during the learning process (James, 1890, Hickcox, 1990). The second type of knowledge, which James' dubbed "knowledge about" includes the information based on giving context to concepts which have been processed through the mind and connected to other stored abstractions. Both types of knowledge held value for James in the broader concept of learning. As he shared in his own words:

We have but to weigh extent against content, thickness against spread, and we see that for some purposes the one, for other purposes the other has higher value.

Who can decide off hand which is absolutely better to live and to understand life? We must do both alternately, and a man can no more limit himself to either than a pair of scissors can cut with a single one of its blades (p. 243)

In James' opinion, experience alone was not enough to stimulate learning, there was also a requirement to examine concepts through thought in order to more completely translate them into knowledge (James, 1890).

Dewey shed new light on the concept of experiential learning as he worked through his development of a progressive educational system. Dewey's (1938) definitive statement in experience and education reads:

“the fundamental unity of the newer philosophy [education based on experience] is found in the idea that there is an intimate and necessary relation between the processes of actual experience and education. If this be true, then a positive and constructive development of its own basic idea depends upon having a correct idea of experience ( p. 20).

With this statement, Dewey forever staked his claim on the integration of education through experiences. Dewey (1938) believed that “all principles by themselves are abstract. They become concrete only in the consequences, which result from their application” (p. 6). These thoughts, and Dewey's resulting educational movement, led to his recognition as one of the most influential educational philosophers of the 21<sup>st</sup> century.

The relationship between current and past experiences was examined by creativity expert Mary Parker Follett during the time of Dewey's progressive education

movement (Follett, 1924). Her musings related to the change which occurs to a person following an experience have been noted by Kolb as influential on the development of the learning cycle in experiential learning theory (Kolb, 2015). Follett stated, “We usually cannot apply what we learn from one experience to the next, because the next will be different. Moreover, it is usually we ourselves who have made the next experience different” (p. 71). This seemingly simple truth would serve as an argument against learning as a two dimensional cycle for integrating new information.

Experiential learning only has learning implications for people who have the cognitive ability to relate learning to experience (Kolb, 1984, 2015). By this token, the integration of Piaget’s work on cognitive development lends to experiential learning. Piaget (1972) put forth the stages of development as related to the ability of a person to grasp abstractions. The four stages progress from infancy through adult and are shown in Table 4.

Table 4

*Piaget’s (1972) Stages of Cognitive Development*

Stage	Age	Description
Sensorimotor	0-2 years	Exploration through direct sensory input and motor contact
Preoperational	2-6 years	Symbols may be used to represent objects, lack of logical reasoning
Concrete Operational	7-12 years	Logical thought is present related to concrete objects
Formal Operational	12+ years	Abstract reasoning and hypothetical thinking are evident

Because experiential learning is most effective when learners connect learning through abstract reasoning (Kolb, 2015), those who are over age 12 would be better equipped from a cognitive development standpoint to fully integrate multiple learning stages into their learning process. In addition, Piaget's work in developing the concepts of constructivism, where learning is most effective when a student can examine new information in light of their previous notions about the topic, have implications for experiential learning theory as it is currently understood (Piaget, 1970).

Experience as a factor in understanding oneself has also been noted in the literature. Carl Rogers (1964) discussed the importance of allowing experience to help define and the importance of allowing past experiences to help a person realize self-actualization. Jung (1973) spoke of the ability to use his experiences to help decode his inner musings as he developed his concepts of self. Other scholars have provided concepts which Kolb (2015) incorporated in the evolutionary development of his experiential learning theory. Kolb (2015) credited Kurt Lewin with the in-the-moment concept deriving from Lewin's (1943) assessments of life space, along with the processes related to theory development. Vygotsky's (1978) social constructivism views and research related to the Zone of Proximal Development led Kolb to relate the experiential learning cycle as a method through which to effectuate Vygotsky's concept of scaffolding information (Kolb, 2015).

David Kolb is credited with combining these concepts into one cohesive theory for learning. Kolb's (1984) experiential learning theory has aspects which draw heavily from the works of the scholars mentioned in this section. His rationale for synthesizing

the works of foundational scholars leading to the creation of both the experiential learning cycle and experiential learning theory is best explained in his own words:

I developed Experiential Learning Theory to integrate the common themes in their [the foundational scholars] work into a systematic framework that can address twenty-first century problems of learning and education. My intention was to describe a theoretical perspective on the individual learning process that applied in all situations and arenas of life (Kolb, 2015, p. xvii).

Through this development, Kolb provides a theory through which curriculum can be developed, instructional methods can be refined, learning preferences can be assessed, and education can be evaluated.

### *Experiential Learning Theory*

Kolb (2015) stated “the aim of experiential learning theory is to create, through a synthesis of the works of foundational scholars, a theory that helps explain how experience is transformed into learning and reliable knowledge” (p. xxi). He posited that ELT is based on the three major “traditions” of experiential learning:

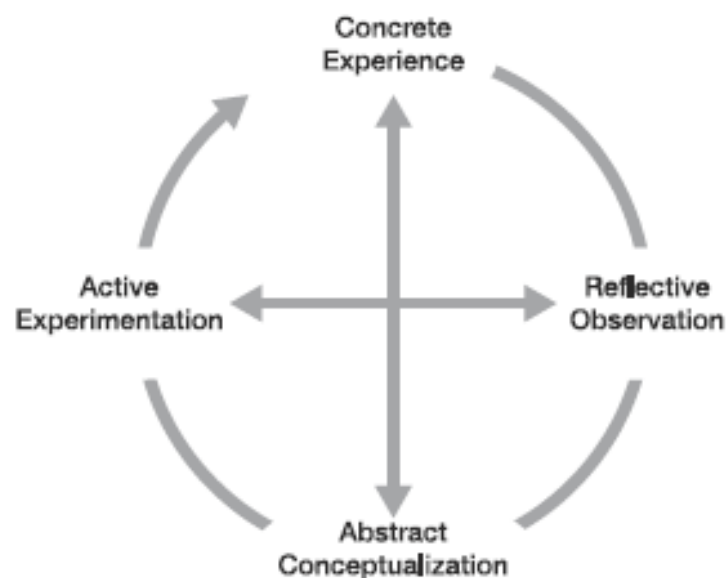
1. Learning is best conceived as a process, not in terms of outcomes;
2. Learning is a continuous process grounded in experience;
3. The process of learning requires the resolution of conflicts between dialectically opposed modes of adaptation to the world.

Within the confines of the three traditions of experiential learning, Kolb (2015) based his development of the experiential learning cycle on three additional characteristics:



1. Learning is an holistic process of adaptation to the world
2. Learning involves transactions between the person and the environment
3. Learning is the process of creating knowledge

The resulting model is the cyclical process of the experiential learning cycle. This cycle includes two sets of dialectically opposed modes of learning: Active Experimentation (AE) and Reflective Observation (RO) in relation to the perception of information, and Concrete Experience (CE) and Abstract Conceptualization (AC) in relation to the processing of information, as shown in Figure 7.



*Figure 7.* Kolb's (1984) original model of experiential learning. Reprinted from Kolb, A. Y., & Kolb, D. A. (2009). The learning way meta-cognitive aspects of experiential learning. *Simulation & Gaming*, 40(3), 297-327. Copyright D. A. Kolb. Reprinted with permission.

Each of the four modes of learning has a basic definition. Kolb & Kolb (2005) shared a succinct definition for each of the learning modes. They describe Active Experimentation (AE) as “learning by doing”, Concrete Experience (CE) as “learning by feeling”, Reflective Observation (RO) as “learning by watching”, and Active Experimentation (AE) as “learning by doing” (Kolb & Kolb, 2005, p. 10)

Kolb (2015) explained the structural process of the learning cycle by describing the two adaptive dialects which are rooted in Piaget’s (1970) aspects of thought, and their eventual resolution. The abstract/concrete dimension deals with the grasping or “taking hold” of experience, through either reliance on abstract conceptualization (comprehension) or concrete experience (apprehension), both related to the dialectic of prehension (Kolb, 2015). In contrast, the active/reflective dimension is related to the transformation of experience, and can be seen as the conflict between active experimentation (extension) and reflective observation (intention). Combining both the prehension dialectic and the transformation dialectic results in building knowledge (Kolb, 2015).

Experiential learning is built on the premise that “learning, and therefore knowing, requires both a grasp or figurative representation of experience and some transformation of that representation. Either the figurative grasp or the operative transformation alone is not sufficient” (Kolb, 2015, p. 67). As there are two separate dimensions for learning, there are four different ways to build knowledge, as shown in Figure 8.

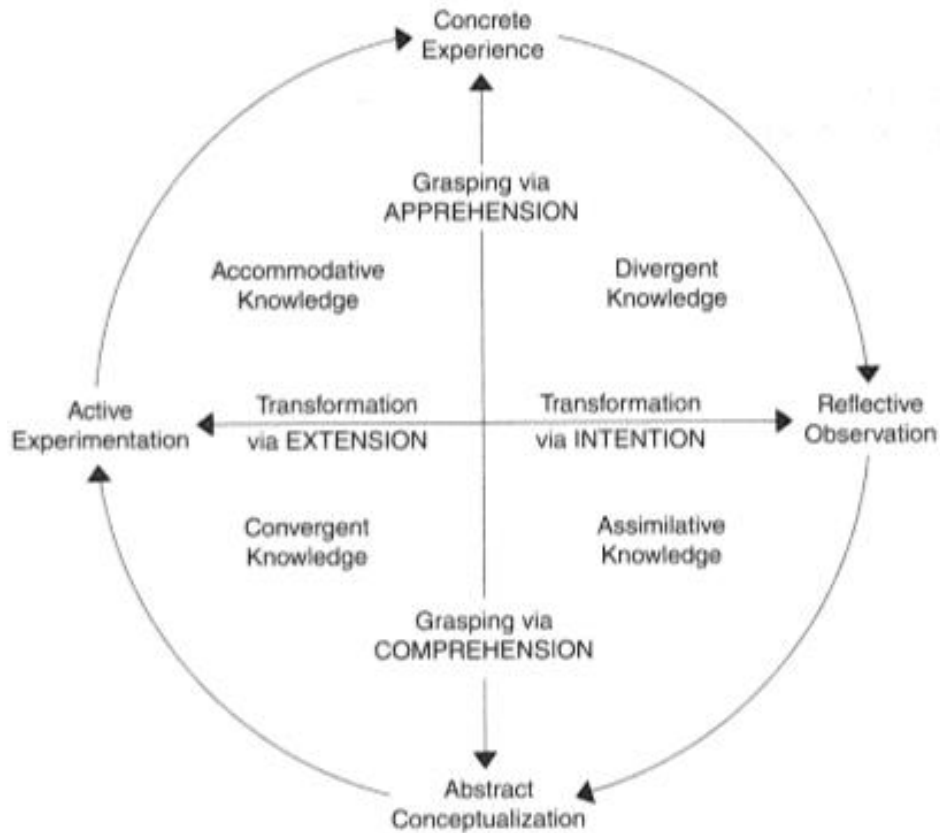


Figure 8. Structural dimensions and knowledge building through ELT. Reprinted from *Experiential Learning: Experience as the Source of Learning and Development* (p. 68), By D. A. Kolb, 2015, Upper Saddle River, NJ: Pearson Education, Inc. Copyright D. A. Kolb. Reprinted with permission.

Information grasped through apprehension and transformed through extension is considered accommodative knowledge, while information grasped through apprehension and transformed through intention is considered divergent knowledge. When information is grasped through comprehension, it can be transformed through extension to result in convergent knowledge, or through intention to form assimilative knowledge (Kolb, 2015). The resulting forms of knowledge (accommodative, divergent, assimilative, and convergent) are the basis for using experiential learning theory to

examine higher levels of cognitive understanding (Kolb, 2015). Each of these types of knowledge can be assessed in order of preference to examine individual learning style.

Kolb (1984) originally proposed experiential learning as a two-dimensional cycle, and posited that individuals differ in the ways they prefer to grasp and transform new information. In the second edition of *Experiential Learning*, Kolb (2015) revised his vision, acknowledging the influence of Mary Parker Follett (1924) and Giddens's theory of structuration, and revising the two-dimensional learning cycle. He explained the cycle not as a flat circle, returning to its origin on each successive round, but as a spiral, in which all four points of the model are incorporated. In his own words, Kolb (2015) outlined "the learning cycle, of course, is not a circle but a spiral where, as T.S. Eliot reminds us, we return again to the experience and know it anew in a continuous recursive spiral of learning" (p. 61).

The increased research between learning theories and neuroscience since the early 1900s has led to findings which indicate linkages between cognitive science and ELT. Zull (2002) explained the physical structures in the brain related to concepts very similar to the four modes of learning in the experiential learning cycle; abstract hypotheses, active testing, concrete experience, and reflective observation. Zull (2002) described the sensory cortex as the portion of the brain responsible for taking in new information through concrete experience, and explained the importance of experience in learning stating "we are more likely to trust sensory input from the experience itself" (p. 145). Research on brain functions shows has led to a better understanding of how the four learning modes of experiential learning theory are processed biological. The

learning form of abstract conceptualization is likely tied to processing in the front integrative cortex, while active experimentation is processed in the motor cortex, and reflective observation processing takes place in the back integrative cortex (Zull, 2002). Zull described the importance of thinking about learning and education through the four modes of ELT, pointing out that the four modes of learning give the brain four times the chance to process, store, and recall information (Zull, 2002)

### *Criticisms and Counterpoints to ELT*

Although experiential learning theory has been widely accepted in many educational arenas (Beard & Wilson, 2006), certain amounts of argument related to the theory and its application exist (Kolb, 2015). Most critical analyses of ELT are based around the central concept that ELT is too individualistic (Kolb, 2015), or that Kolb's interpretation is based on incomplete analyses of the foundational scholars (Beard & Wilson, 2006).

Critics who fault ELT as an individualistic expression of learning (Fenwick, 2000; Michelson, 1999; Reynolds, 1997, 1998; Vince, 1998) have disparaged the theory as an approach to learning which relies on the experience of each individual, and criticize ELT as a theory built on individualized learning but generalized to a broader audience (Reynolds, 1997; Michelson, 1999). They often cite the lack of detail given in ELT to the grouping variables of social culture, community, or political environment (Holman, Pavlica, & Thorpe, 1997; Vince, 1998). Kolb (2015) defends the position of ELT as a holistic theory of learning by stressing the importance of mankind being able to develop autonomously.

Miettinen (2000) is one of several critics who have faulted ELT as oversimplified and failing to completely incorporate foundational works. Miettinen (2000) viewed ELT as lacking Dewey's thoughts on the importance of habit as a factor in learning. In addition, Miettinen maintains that Kolb's work fails to completely incorporate the Lewinian Model as originally intended. Kolb (2015) maintains that his development of ELT was a combination of the works of the foundational scholars and is "soundly based in intellectual traditions of social psychology, philosophy, and cognitive psychology" (p. 3).

Strong support exists for the theory as a basis for examination of learning, even though there are critics of its development and interpretation. ELT continues to be a well-respected and viable framework for the examination of student learning, especially in applied settings (Beard & Wilson, 2006). Criticisms of any theory are useful, as they often drive the refinement and continued modification of a knowledge base in a particular area (Reigeluth, 2013). This study employed ELT as both a framework for understanding and as the basis for instrumentation related to the independent variable of learning style.

### *ELT and Learning Styles*

As mentioned earlier in the chapter with regard to student factors influencing learning, the concept of learning styles refers to individual preferences for one type of learning over another (Sousa, 2011). ELT is built upon a foundation which relies on individual experiences to build individual learning, due in part to its roots in constructivism (Kolb, 2015). The tie between experiential learning theory and

individual learning styles is aided by the fact that David Kolb had extensive training as a personality theorist (Kolb, 2015). The structure of ELT as the interaction between ipsative poles in both grasping and transforming information is a key concept which lends support to the relationship between ELT and learning styles.

The descriptions for each of the modes of learning are outlined in the *KLSI version 3.2 workbook* (Kolb & Kolb, 2013), shown in Table 5.

Table 5

*KLSI Description of Modes of Learning (Kolb & Kolb, 2013)*

Learning Mode	Description	Characteristics of individuals with preference in this mode
Active Experimentation	Learning by doing	the ability to get things done, take risks, and influence people and events through action
Concrete Experience	Learning by experiencing	Learning from specific experiences, relating to people, being sensitive to feelings and people
Reflective Observation	Learning by reflecting	Observing carefully before making judgments, viewing issues from other perspectives, looking for the meaning of things
Abstract Conceptualization	Learning by thinking	Analyzing ideas logically, planning systematically, acting on an intellectual understanding of a situation

Kolb (1984) described each of the ends of the continuums as the extent to which individuals had preferences for each of the characteristics, saying that learning is the “generalized differences in learning orientation based on the degree to which people

emphasize the four modes of the learning process” (p. 26). In his own words, Kolb explained how ELT can relate to learning preferences, Kolb (2015) stating:

The complex structure of learning allows for the emergence of individual, unique possibility-processing structures or styles of learning. Through their choices of experience, people program themselves to grasp reality through varying degrees of emphasis on apprehension or comprehension. Similarly, they program themselves to transform these prehensions via extension and/or intention (p. 100).

Building upon the natural partialities individuals have with regard to grasping and transforming experience, Kolb used ELT to develop an inventory which would assess these preferences (Kolb, 2015).

The resulting assessment was the first version of *Kolb’s Learning Style Inventory (KLSI)*. According to Kolb:

We were seeking a test that was both *normative*, allowing comparisons between individuals in their relative emphasis on a given learning mode, such as abstract conceptualization, and *ipsative*, allowing comparisons within individuals on their relative emphasis on the four learning modes- for instance, whether they emphasized abstract conceptualization more than the other three learning modes in their individualized approach to learning (p.104).

*KLSI v. 1* was a nine-item self-description questionnaire, sorting respondents into one of four learning styles, which were directly related to the four forms of knowledge: accommodative, divergent, assimilative, and convergent. Through the progression of



*KLSI* versions, the instrument has been refined. Kolb originally broke down learning styles into four categories, based on the type of knowledge created, in line with the four types of knowledge shown in Figure 8. These four categories were determined based on an individual preference for perceiving information (AE – RO) and processing information (AC – CE), the resulting category placed individuals in one of the four learning styles; accommodating, diverging, assimilating, converging.

Further refinement of the *KLSI* (Abby, Hunt, & Weiser, 1985) led to the expansion of *KLSI* styles into nine separate learning styles, rather than the four shown in the initial version of the instrument. The nine styles outlined in version 3.1 of the *KLSI* are shown in Figure 9.

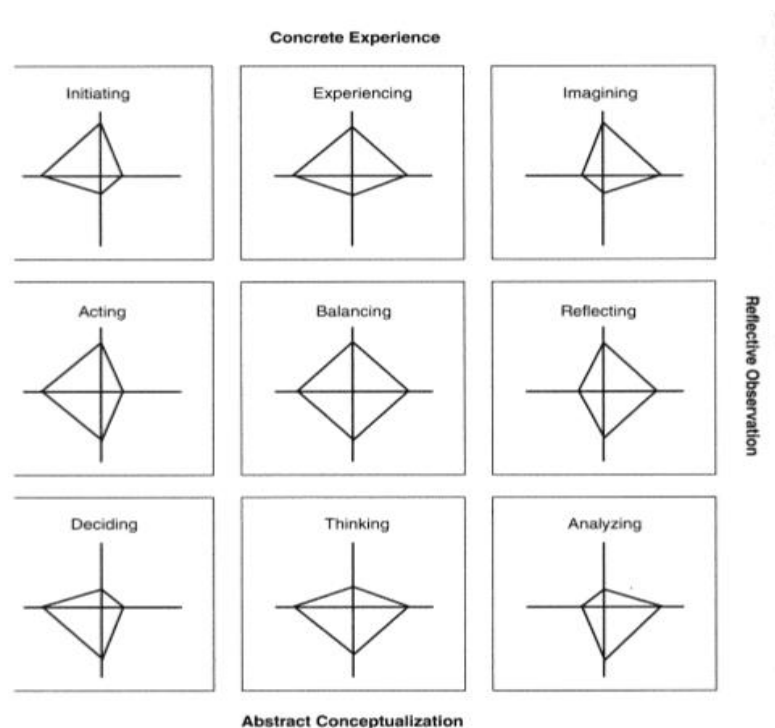


Figure 9. *KLSI* v. 3.2 learning styles. Copyright Haygroup (2013). Reprinted with permission

Kolb & Kolb (2005) stated the importance of using nine styles in highlighting the continuous nature of movement along the processing and perceiving continuums. The nine learning styles allow for more variation in preference for grasping and transforming information and allow for more accuracy in ascribing a specific learning style aligned with personal preferences.

Analyzing student learning within the parameters of KLSI score allows researchers to examine the role student processing and perceiving have on overall learning in specific content areas and applications (Kolb, 2013).

### *ELT in Agricultural Education*

Agricultural education has strong foundations in learning through experience (Roberts, 2006). There are numerous ties to experiential learning concepts within the foundation of agricultural education. For example, the official motto for the National FFA Organization begins with the lines “learning to do” and “doing to learn”, and one of the components of the three-circle model for agricultural education is the Supervised Agricultural Experience (Croom, 2008). Roberts (2006) posited that agricultural education has the same philosophical roots as experiential learning.

Baker, Robinson, and Kolb (2012) examined the philosophical relationship between agricultural education and experiential learning theory. Their findings were instrumental in helping to build a model with each of the four modes of experiential learning embedded within each of the three circles of the agricultural education model- and also as overarching modes relating to the interaction of all three components of agricultural education (Baker, et. al., 2012). They cautioned against the historical view

of agricultural education where SAEs are the only portion touted as experiential learning, and recommended philosophical shifts so ELT could be viewed as a component of each portion of agricultural education (Baker, et. al., 2012). In addition, they stated “paucity of research exists demonstrating the effects of experiential learning methods on learning in secondary education, including agricultural education” (p. 13).

In response to this finding, Baker (2012) conducted a clinical examination of the differences in student learning in and among groups when comparing the teaching methods of direct instruction and experiential learning with a group of secondary agricultural education students. More specifically, the examination looked at the impacts on learning related to student ability in the areas of analytical and practical thinking, creativity, and motivation. His findings suggested that differences existed in student performance between groups receiving indirect and experiential learning instruction when student motivation was considered as an outcome variable.

An additional experiment was conducted by Baker, Brown, Blackburn & Robinson (2014) to determine if the order of abstraction and type of reflection impacted overall student scores. Their exploratory examination provided a glimpse into the concept of sequencing ELT concepts in agricultural education. The findings of their exploratory experiment led them to conclude that the order of abstraction and type of reflection resulted in no significant differences for the post-secondary experimental groups.

## **Relationship Between ELT and Cognitive Sequencing**

Experiential learning theory has four distinct modes of learning, organized around two dimensions of grasping and transforming information. Within this framework, it may be easy for one to assume that Kolb suggested both a starting and ending point for the cycle. However, Kolb's view of the sequence for the four learning modes is not prescriptive. He states that the cycle may be entered at any point, and gives only a caution that the stages should be followed in sequence from wherever the learner begins (Kolb, 2015). Very rarely does the concept of a particular sequence related to the learning cycle appear in ELT literature.

The foundational scholars of ELT showed a preference for beginning the cycle with concrete experience. William James described what may be considered the first outline directly influencing the learning cycle. To explain his views on experience, he said:

It [the experience] is only a that. In this naif immediacy it is of course valid, it is there, we act upon it and the doubling of it in retrospect into a state of mind and reality intended thereby it is just one of the acts. The 'state of mind' first treated explicitly as such in retrospection will stand confirmed (James, 1912, p. 23).

Kolb (2015) analyzed this statement on the learning cycle and interpreted James' intent to begin with concrete experience, move to an active experimentation stage, follow with reflective observation, and finish with abstract conceptualization. Dewey (1916) discussed the concept of having an experience prior to gaining knowledge about a topic, and his theories behind the superiority of primary experience to secondary experience

lead to his likely view of concrete experience as the beginning of learning through experience.

Kolb (1984, 2015) posited that ELT is a recursive cycle through which knowledge is created by grasping and transforming information, and outlines knowledge creation as the transformation of information from the prehension dimension. This dimension relies on the reconciliation between sensory input and abstract thought. In essence, prehension encompasses James' (1890) dual knowledge theory and allows the learner to both have both concrete and tacit knowledge of the subject learned.

Traditional education has been rooted in the comprehension end of the prehension dimension. Quite often, instruction in abstract concepts precedes concrete experiences related to those concepts (Reigeluth, 2013). For example, in many horticulture science courses in agricultural education the topic of flower anatomy is instructed including a concrete flower dissection component. No fewer than five separate commercially available curricula are available with a unit including flower anatomy, and all include a flower dissection laboratory. In each of these curricula, the suggested instruction includes sharing the definition of flower structures in an entirely different day than the laboratory. These curricula are an example of the prevalence of presenting an abstract conceptualization preceding a concrete experience in many agricultural educational settings. The same is true across the broader landscape of education (Reigeluth, 2013)

Kolb explains comprehension as “secondary and somewhat arbitrary ways of knowing” (p. 69), yet much of the curricula in modern education is designed with

comprehension activities preceding apprehension. This study has been designed to examine the prehension dimension, and evaluate student knowledge when information is presented at both ends of this continuum related to specific student factors.

### **Summary**

As agricultural education strives to meet the needs of STEM education, increased research into effective methods for teaching STEM concepts must be examined. In order to more fully examine this topic, the tie between STEM education and agricultural education must be related to not only what agricultural educators are teaching, but how they are teaching it.

The literature reveals strong ties between STEM concepts and Career and Technical Education. Stone's (2010) Math-in CTE project and Pearson's (2015) Science-in-CTE project have paved the way for research of highly abstract STEM concepts within the realm of CTE. Agricultural education has taken on the challenge of instructing STEM components within the curriculum, as agricultural educators have high perceptions of the importance and necessity of incorporating these concepts in their programs (Brister & Swortzel, 2009; Scales, Terry & Torres, 2009; Smith, Rayfield, & McKim, 2015; Thompson & Balschweid, 2000). Although there are ties between all four aspects of STEM and agricultural education, the area with the most expansive research is science. Experimental research must only be conducted in areas where established connections have been made through the discoveries of previous research (Shadish, et. al., 2002). Therefore, this study built upon and relied on research related

specifically to how science concepts could be more effectively integrated into agricultural education curricula.

There are innumerable factors that impact student learning on an individual level. These factors include school, teacher, and individual student differences (Carroll, 1989). It would be highly improbable to incorporate all of these factors as variables in this study (Darling-Hammond & Bransford, 2005; Frankel & Wallen, 2006). However, within the scope of this study, it was logistically and practically possible to classify students based on their socioeconomic status, ability to learn, and learning style.

Historically, students with lower SES have performed lower on STEM concepts, an important factor to consider for agricultural education students who fall into a low SES classification (Sirin, 2005; White, 1982). Examining their learning in the context of science concepts within agricultural education may help reveal the most effective sequence for presenting information to those who are underperforming.

Learning styles have been met with some disagreement as to their impact on student learning (Fenwick, 2000; Michelson, 1999; Miettinen, 2000; Reynolds, 1997, 1998). Although not all experts agree in specific methods for assessing student learning style, it can be agreed that students differ in their preferences for the methods and environments for learning (Sousa, 2011; Tomlinson, 2015). The framework for this study is based partially in Kolb's experiential learning theory, which allowed for individual assessment of student learning style through the employment of the *KLST* instrument (Kolb, 1984; 2015; Kolb & Kolb, 2013).

Students with learning disabilities are often at a disadvantage when it comes to grasping complex concepts in STEM education (Woodward & Montague, 2002). In addition, secondary CTE courses, including agricultural education, often include a higher percentage of students with learning disabilities than their respective schools, increasing the importance of finding effective STEM teaching methods which can reach this population of students (Wagner, et. al., 2015). Students both with and without IEP modifications were classified in this study, and learning was compared between these groups to note differences which may occur.

The presentation order of instruction while learning new concepts has been examined through many different theorists (Reigeluth, 2013), and cognitive sequence may play a role in understanding STEM concepts in agricultural education. Much of the discussion related to cognitive sequencing is related to the ordering of information based on cognitive level (Anderson, et. al., 2001; Bloom, 1956; Webb, 1997).

Experiential learning provided the framework for presenting information through this study, and gave structure to the cognitive sequencing tested through the experimental treatment. Through the four learning modes of active experimentation, concrete experience, reflective observation, and abstract conceptualization, learning can be examined in both how information is grasped and transformed (Kolb, 2015). As such, the learning style inventory selected for this study was aligned to the concepts of ELT.

Cognitive sequencing in this study was an examination of the prehension dimension of grasping information. The experimental treatments in this research were



based on the dual dialectics of apprehension, which is grasping through experience, and comprehension, which is grasping through abstraction (Kolb, 2015). Each student in the study was exposed to two units of instruction, one which presented new concepts beginning with apprehension and one which presented new concepts beginning with comprehension. Through combining cognitive sequencing principles and an examination of student factors, student learning in STEM context areas can be evaluated to see if interactions existed.

## CHAPTER III

### METHODS

This study was a quasi-experiment using a crossover design with repeated measures and randomized groups (Shadish, et. al., 2002). Treatment exposure was conducted in two-rounds to allow a complete crossover of treatments (Campbell & Stanley, 1963). Separate high school classes were identified for the experiment, and instruction in each of two experimental units of instruction was completed by regular agricultural educators at each of the selected sites. Instructors were trained in the utilization of the curriculum materials provided. This section will further discuss the methods used to answer the research question including; research design, development of experimental treatments (including instrumentation), research procedures, population and sample, data analysis, and threats to internal and external validity.

#### **Research Question**

The purpose of this study was to determine the effect of cognitive sequencing within the prehension dimension on student performance on STEM content assessments in agricultural education. This study also examined the interactions between cognitive sequencing and learning style inventory score, socioeconomic status, and learning disabilities. To accomplish this purpose, the study design was developed to answer the following research question:

1. What interactions exist between the factors of cognitive sequence, learning style, socioeconomic status, and learning disability on student performance on STEM content assessments in agricultural education?

## **Experimental Design**

This study was conducted using a quasi-experimental design, utilizing intact Principles of Agriculture, Food, and Natural Resources (AFNR) classes in secondary classrooms in Texas as the functional experimental units. Quasi-experimental research was popularized by Campbell and Stanley (1963) and can be defined as “an experiment in which units are not randomly assigned to conditions” (Shadish et. al., 2002, p. 511).

The use of quasi-experimental design allows researchers to conduct causal inference in situations where clinical experimentation is not practical. As Shadish and Cook (1999) explain:

Those of us who toil in the trenches of fields like psychology, education, and economics know that random assignment is what we would like to do, but that quasi-experiments are what we are sometimes forced to do for practical or ethical reasons (p. 294).

Statisticians and psychometricians have worked toward identifying experimental design features which could strengthen the use of quasi-experimental studies for causal inference. Through this examination, several features of design have been suggested which can aid causal inference in quasi-experimental designs (Shadish, et. al., 2002).

The experimental component of this research was conducted using intact high school secondary agriculture classes. Instructors were trained in the utilization of the curriculum models provided. The experiment used a repeated measures crossover design including a control group (Campbell & Stanley, 1963; Shadish, et. al., 2002) to allow for multiple data collection points from each student.

To accomplish the experiment, two units of instruction were developed for the Principles of AFNR courses, one in water science and the other in soil science. Both units were developed in two different formats, one sequenced to present each scientific concept within the unit to students first with a concrete experience (apprehension), and the second unit sequenced to present each scientific concept beginning with abstract conceptualization (comprehension). Each test unit (site) received both content areas, and sites were randomized as to which content area and cognitive sequence they would receive first. The resulting model allowed each student to experience both units of instruction and both cognitive sequences.

The basic experimental design for this study is outlined in Table 6. One site served as the control group, taking both the pre and post-test observations for both of the content units without receiving instruction. Each of the remaining four sites completed a pretest, then received instruction randomized as to both the content and cognitive sequence, followed by a posttest. The process was repeated for each of the groups with round two being instructed in the opposite content and cognitive sequence.

Table 6

*Basic Experimental Design by Round*

Group		Round One Treatment			Round Two Treatment	
G <sub>1</sub>	O <sub>1</sub>		O <sub>2</sub>	O <sub>3</sub>		O <sub>4</sub>
G <sub>2-5</sub>	O <sub>1</sub>	X	O <sub>2</sub>	O <sub>3</sub>	X	O <sub>4</sub>

### *Conditions of Quasi-Experimental Research*

Shadish et. al. (2002) set forth that quasi-experiments require the same four conditions as traditional experimental research. These requirements are; variation in the treatment, post-treatment measures of outcome, at least one unit undergoing an observation, and a mechanism for inferring what the outcome would have been without the treatment. To meet the requirements of this research design, this study carefully adhered to the four conditions.

To meet the first requirement of experimental research, variation existed in the treatments for groups within this study. Groups received two units of instruction, in sequences which were randomly assigned as either AC-CE or CE-AC. In addition, variation existed for both which content was given in each sequence and which content was taught first. To meet the second condition, pretest and posttest measures were collected for each group in both rounds. Each participant had four collected outcome data points; curriculum one pretest, curriculum one posttest, curriculum two pretest, and curriculum two posttest. All of the units in this experiment were observed, fulfilling the third condition of experimental research. To meet the final condition of experiments, both the crossover in design and comparison group provided information related to the outcome in the absence of treatment.

### *Design Features*

The design features suggested for strengthening quasi-experimental studies are: some form of randomization in the assignment of treatments, use of multiple or repeated measures, use of comparison groups, and varied application of treatment to multiple

groups (Shadish, et. al., 2002). This study was designed to incorporate design features from each category. As Shadish noted “adding more design elements is a way to gather more elaborate and diverse data in the service of improving causal inference” (p. 161).

Five high schools were used as the groups for this study. In each school, all of the Principles of AFNR students taught by a participating teacher were considered one site. To introduce an element of randomized assignment, these five sites were each assigned a number, and a random number generator was used to assign each to one of the sites to one of five treatment profiles, as shown in Table 7.

Table 7

*Experimental Treatment Profiles by Site*

Site	<u>Round One</u>				<u>Round Two</u>			
	Curriculum	Sequence			Curriculum	Sequence		
1	O <sub>1</sub>	--	--	O <sub>2</sub>	O <sub>3</sub>	--	--	O <sub>4</sub>
2	O <sub>1</sub>	Water	AC-CE	O <sub>2</sub>	O <sub>3</sub>	Soil	CE-AC	O <sub>4</sub>
3	O <sub>1</sub>	Soil	AC-CE	O <sub>2</sub>	O <sub>3</sub>	Water	CE-AC	O <sub>4</sub>
4	O <sub>1</sub>	Soil	CE-AC	O <sub>2</sub>	O <sub>3</sub>	Water	AC-CE	O <sub>4</sub>
5	O <sub>1</sub>	Water	CE-AC	O <sub>2</sub>	O <sub>3</sub>	Soil	AC-CE	O <sub>4</sub>

*Note.* Site 1 served as the control and therefore did not receive instruction for either round of this experiment.

The resulting randomized treatment profiles allowed for each of the possible cognitive sequences to be examined in both content areas and with both sequences. Site one served as a control group, receiving no cognitively sequenced instruction and completing only the pre and posttests for each curriculum unit.

Due to circumstances beyond the control of this experiment, the instructor at site five was unable to complete the full treatment, and as such, the site and resulting data

were excluded from analyses. At the end of the data collection period, four sites completed the treatments and were included.

The second suggested design feature for quasi-experimental research is the use of repeated or multiple measures. In this study, students completed both pre and posttest assessments for each unit of instruction. These repeated measures were identical for each of the sequenced units; the water unit pretest and posttest were identical for students who received the instruction sequenced AC-CE and those who received the instruction sequenced CE-AC and vice versa for the soil science unit. Students completed a total of two rounds of repeated measures to provide four data points. The resulting differences in score from beginning to end of unit for each student served as the dependent variables for this experiment. Using the difference scores rather than utilizing the repeated measures data analysis is suggested for crossover designs (Tabachnick & Fidel, 2007) as it allows the treatment to be analyzed as a factor and prevents misleading data from the crossed treatments entering the analysis.

The third design feature included in this study was use of a comparison group. In order to have information related to baseline knowledge of students in both water and soil science, and to have a group with which to compare experimental treatment results, one of the assigned treatments was a control group. This group received no instruction in either water or soil science between observations. The use of a comparison group lends stability to the inference of causality in quasi-experimental studies (Shadish, et. al., 2002).

A final design feature included in this study was the use of crossover in treatment. To decrease threats from differences in content area and which content was presented first, treatment groups were randomly assigned to receive both types of cognitive sequencing. The complicated nature of conducting experiments with human subjects leads to the impossibility of controlling for individual variation (Rosenbaum, 2002). According to Rosenbaum (2002) one of the most basic ways to control for this variation is to include a crossover in the design of the experiment. A crossover allows for individual differences based on specific variables to be examined, essentially allowing each individual to serve as their own control (Shadish, et. al., 2002). While we are unable to account for individual variation, we can examine collective differences for many different and highly varied individuals between treatments (Campbell & Stanley, 1963; Rosenbaum, 2002). This is a highly recommended practice when dealing with factors which stimulate complicated and multi-faceted processing in individuals, like learning (Shadish, et. al., 2002).

Shadish posed the question “is there an ideal or best quasi-experimental design, one that assembles these elements optimally? The answer is, usually not” (p. 160). He continued by stressing the importance of added design features to strengthen analyses by saying “when the design features are added to the interrupted time series, the result is a quasi-experiment whose inferential yield sometimes rivals that of the randomized experiment” (p. 161).



### *Variables*

The complex nature of the research question in this study relied on a multivariate analysis of the data. According to Meyers, et. al. (2013)

We all seem to agree that individuals generate many behaviors and respond in many different although related ways to the situations they encounter in their lives. Univariate analysis by definition, are able to address this level of complexity in only a piecemeal fashion because they can only examine one aspect at a time. Multivariate analysis allows us to do this as well, but also affords us the opportunity to examine the phenomenon under study by determining how the multiple variables interface (p. 4).

This description of the importance of multivariate analysis relates well to the examination of cognitive sequencing of STEM concepts in agricultural education, as there are likely many factors which play a role in student learning.

Quasi-experimental research involves an examination of the independent variables and their relationship to a single or multiple dependent variable (Meyers, et. al., 2013; Shadish, et. al., 2002). By examining independent and dependent factors, we may be able to determine causal relationships and interactions between factors to explain observed variation in student scores (Shadish, et. al., 2002).

This study involved the examination of two dependent variables, both based on the change in a student's score from pretest to posttest on cognitively sequenced units. One DV is the change in score for the water science unit, while the other is the change in score for the soil science unit. Examining these two dependent variables helped to

determine whether or not differences existed based on the manipulation of cognitive sequence, which was included as an independent variable.

An examination of these dependent variables with the additional information related to the independent variables was conducted to see if interactions existed. According to Rosenbaum (2012) the variables of interest for a quasi-experimental study should be those which are: a) found in the literature to be potential contributors to outcome variables, and b) are within the means of the researcher to collect in the given situation. Based on the review of literature in Chapter 2, the interaction between the dependent variables and the independent variables of learning style, socioeconomic status, learning disabilities, and cognitive sequence emerged as the viable variables of interest in this study. The resulting list of variables is found in Table 8.

Table 8

*Variables in Study Design*

Variable Name	Variable Type	Data Type
KLSI Type (Dichotomous AC or CE preference)	IV	Nominal
Socioeconomic Status	IV	Nominal
Learning Disability Classification	IV	Nominal
Experimental Group (Sequence of Units)	IV	Nominal
Change (Posttest – Pretest) Water Science Unit	DV	Scale
Change (Posttest – Pretest) Soil Science Unit	DV	Scale

These variables highlight information directly related to answering the research question. It is important to note the influence of confounding variables on all quasi-experimental research (Meyers, et. al., 2013; Shadish, et. al., 2002). The presence of

confounding variables is a limitation to generalizing the results of this study to outside populations. These potential confounding variables included those factors of learning which could not be classified on in the scope of this research (Carroll, 1989). In educational research, the most effective approach is one which classifies the variables which are within the control of the researcher (Frankel, et. al., 2006), and uses as many design features as possible to minimize the risk of confounding variables on data collection (Shadish, et. al., 2002).

### **Development of Experimental Treatments**

Two units of experimental curricula were developed for this study. Each unit was developed in two formats; one cognitively sequenced with each new concept presented beginning with a concrete experience (apprehension) and moving toward abstract conceptualization (comprehension), and another with each new concept presented beginning with abstract conceptualization (comprehension) and moving toward a concrete experience (apprehension). The curricula, instrumentation, and training warrant further discussion.

#### *Experimental Curricula*

Both cognitively sequenced units included pretests and posttest which were identical, regardless of the sequence of presentation. To ensure curricula met the rigorous requirements for use as experimental treatments, they were designed and verified to meet specific criteria to hold constant the unit objectives, daily objectives, activities, link and motivation, and formative assessments. To accomplish this,

curriculum design was guided by Gagne’s nine events of instruction (1965), as shown in Table 9, which served as the foundation for development of lessons.

Table 9

<i>Lesson Plan Design Aligned with Gagne’s (1965) Nine Events of Instruction</i>		
Instructional Event	Water Science Unit	Soil Science Unit
Gaining Attention	Constant	Constant
Informing users of objective	Constant	Constant
Stimulating recall of prior knowledge	Constant	Constant
<i>Presenting the stimulus</i>	<i>Varied</i>	<i>Varied</i>
Providing learning guidance	Constant	Constant
Eliciting Performance	Constant	Constant
Providing Feedback	Constant	Constant
Assessing Performance	Constant	Constant
Enhancing Retention and Transfer	Constant	Constant

All events were held as constants during each round of testing with the exception of “presenting the stimulus” which varied based on which method of grasping experience was presented first. Gagne (1965) theorized that by following the nine events of instruction, external learner variables can be controlled in test groups.

The two units of instruction selected for development in this experiment were water science and soil science. There were several practical reasons for selecting these particular unit topics. First, the vast majority of students enrolled in Principles of AFNR were freshmen. As such, they were not likely to have taken a secondary level chemistry course (Texas Education Agency, 2015), which would expose them to the embedded science concepts in these units. In addition, both water and soil science are listed in the

Texas Essential Knowledge and Skills (TEKS) for the Principles of AFNR courses. A final factor in the selection of these topics was the need for units to be similar in length, difficulty, and number of science concepts presented.

Each unit of instruction was developed for presentation in five, 45 minute class periods. The curriculum included lesson plans and activities for four days of instruction and a fifth class period was allowed for completing the unit assessment. The cognitive level for all instructional methods was determined during curriculum development and the presentation for each day of instruction was purposively selected to meet the treatment requirements. An example of parallel lessons sequenced from both AC-CE and CE-AC can be found in Appendix A.

To establish content and face validity, the units of instruction were reviewed and verified by both curriculum development experts in agricultural education, secondary agricultural educators, and a cognitive psychologist specializing in curriculum development. These experts provided guidance and insight into both the format and design of the lessons, along with verification that the ELT learning modes for each activity had been determined correctly.

To maintain congruence between the two different units of instruction, several items were held constant from one content to another. These constants included length of instruction, number of experiential activities, cognitive levels for each day of instruction, and cognitive levels of questions on unit assessments.

### *Instrumentation*

There were three instruments used in this study. The first two were the content knowledge assessments on the water and soil science units. The third was the *KLSI v 3.1* which was used to determine the independent variable of learning style in study participants.

### **Unit Assessments**

Each unit was presented with the same objectives, and therefore instruction was aimed at preparing both groups for the unit assessments. Criterion-referenced unit assessments were distributed and taken by participants on day five of the unit. Unit assessments were developed to take into account direct assessment on each of the unit objectives, and had exam questions at multiple levels of cognition. Linkages between individual instrument items and objectives, along with cognitive levels of exam items were established during instrument development. Question scores were weighted with regard to cognitive level, with questions written at higher cognitive levels receiving more points than those written at more basic levels of cognition. Careful attention was taken to ensure assessments for both units were presented with the same breakdown of cognition levels

Participating students took identical pre and posttest assessments for each of the units, with the answer and question orders reorganized in the pre and posttest measures. The format of the unit exam included multiple choice, fill in the blank, and application questions. An example of a common unit assessment, with ties to each objectives, can

be found in Appendix B, and a crosswalk to the weighting of cognitive levels can be found in Appendix C.

To establish the content and face validity of unit exams, Crestwell (2008) suggested review by a panel of experts. University teacher educators, secondary agricultural educators, and curriculum development faculty at Texas A&M were used as the panel of experts to determine the content and face validity of the unit assessments. This group of experts deemed the assessments for both units as appropriate for the Principles of AFNR course and students.

Establishing reliability of the unit assessments was completed post hoc. Campbell and Stanley (1963) stated that post hoc reliability is appropriate in cases where an exploratory examination of a topic is conducted. The pre and posttest assessments for each unit were examined for scaled reliability using Cronbach's  $\alpha$  coefficient. Resulting coefficients yielded  $\alpha = 0.72$  and  $\alpha = 0.83$  for the water science pre and posttests and  $\alpha = 0.68$  and  $\alpha = 0.76$  for the soil science pre and posttests respectively. According to Nunnally and Bernstein (1994), an alpha of .70 or higher is an acceptable reliability measurement; however, a lower alpha is not necessarily a detriment (Nunnally, 1978). Nunnally (1978) concluded that in the early stages of research it may be acceptable to have only modest reliability, which Nunnally classified as an alpha level above 0.60.

After calculating the scaled reliability for each instrument, additional measures of reliability were desired. According to Frisbie (1988), the most appropriate method for determining the reliability of a typical teacher-made test using multiple question formats is through the employment of a *KR-20* coefficient. Each item on the unit assessments

were scored in regard to “correct” or “incorrect” responses on factors for multiple items. Per the suggestion of Frisbie (1988), the *KR-20* coefficient was calculated after entering the correct or incorrect response for each student on each item for each assessment.

Resulting coefficients (*KR-20*) were 0.75 for the water science pretest and 0.78 for the water science posttest. For the soil science tests, the resulting reliability coefficients (*KR20*) were 0.81 for the pretest and 0.86 for the posttest. According to Frisbie (1988), reliability coefficients for teacher-made tests are considered to be acceptable at a minimum level of 0.65. Therefore, the reliability of both unit assessments were deemed acceptable for the intended purpose of this study.

### **KLSI v. 3.1 Instrument**

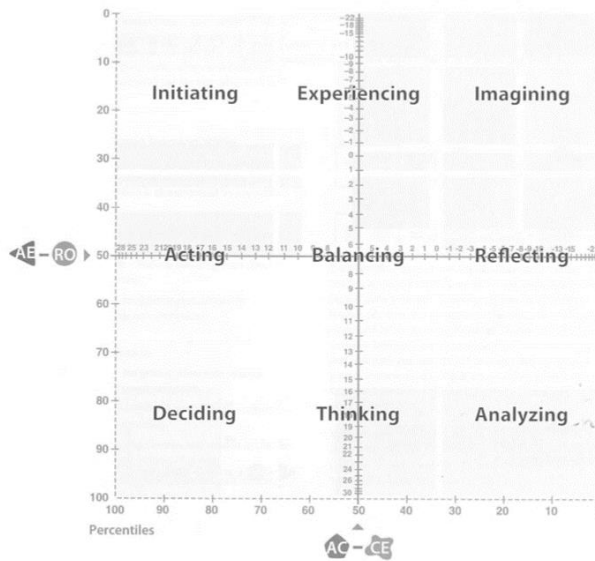
To determine the learning style preference for respondents in regard to grasping information, the paper version of the *KLSI v. 3.1* instrument was used. This instrument is commercially available from Haygroup, and previously described in relation to ELT in Chapter 2. The format of *KLSI v. 3.1* is a forced-choice response to 12 instrument items. Each item contains a sentence prompt and asks respondents to rank their preferences for four answer choices, which correspond to the four learning modes of Kolb’s (1984) experiential learning theory (ELT). Respondent rankings are ordinal from 4 “most like me” to 1 “least like me” (Kolb & Kolb, 2013).

Validity of the *KLSI v. 3.1* has been widely established for use in the field of education (Kolb & Kolb, 2005). Validity was determined to be acceptable for the purposes of this study. Previous measures of reliability for the four learning modes



included in the KLSI range from  $\alpha = 0.77$  to  $\alpha = 0.84$  (Kolb & Kolb, 2005a). As such, the reliability was determined to be suitable for use in this study.

Based on responses to the 12 items on the instrument, participants were classified into one of nine learning styles (Kolb & Kolb, 2013). The learning styles are related to preferences for both the grasping (prehension) and transforming experience, as shown in Figure 10. The resulting styles and descriptions are shown in Table 10.



*Figure 10.* Learning style grid for the *KLSI* instrument. Depicts preference for grasping (AE-RO) and transforming (AC-CE) information. Copyright Haygroup (2013). Reprinted with permission.

Although the population of this study was large, an unequal representation of learning styles exists among the general population (Kolb, 2015). In order to maintain group sizes large enough for statistical examination, the decision was made to use the results from the KLSI scores for the ipsative relationship between concrete experience

and abstract conceptualization to classify participants based on their preference for grasping information through apprehension (CE) or comprehension (AC). This decision is similar to the decision to use a bipolar classification of preference for grasping and transforming information by Baker (2012). Cut scores from the *KLSI* technical manual were used to determine preference for apprehension or comprehension. An ACCE score below seven allowed classification as a preference for apprehension, and a preference for comprehension was determined with an ACCE score of 8 or higher (Kolb & Kolb, 2013). The resulting preference for apprehension or comprehension was used as the independent variable related to learning style.

Table 10

*KLSI Styles (Kolb, 2015)*

Style	Prehension Preference	Transformation Preference	Characteristics
Initiating	Apprehension (CE)	Extension (AE)	Ability to initiate action in order to deal with experiences and situations
Experiencing	Apprehension (CE)	Balanced	Ability to find meaning from deep involvement in experience
Imagining	Apprehension (CE)	Intention (RO)	Ability to imagine possibilities by observing and reflecting on experiences
Reflecting	Balanced	Intention (RO)	Ability to connect experience and ideas through sustained reflection
Analyzing	Comprehension (AC)	Intention (RO)	Ability to integrate and systematize ideas through reflection
Thinking	Comprehension (AC)	Balanced	Capacity for disciplined involvement in abstract and logical reasoning.
Deciding	Comprehension (AC)	Extension (AE)	Ability to use theories and models to decide on problem solutions and courses of action.
Acting	Balanced	Extension (AE)	Strong motivation for goal directed action that integrates people and tasks
Balancing	Balanced	Balanced	Ability to adapt; weighing the pros and cons of acting versus reflecting and experiencing versus thinking

### *Treatment Delivery and Training*

The units of instruction created as the experimental treatments for this study were designed to be instructed in a specific manner, using the provided lesson plans, worksheets, laboratories, and information. Completing this research within the parameters of the study design relied heavily on the teachers at each experimental site instructing the curricula exactly as designed. The possibility of deviation from the intended curricula posed a limitation to this study. To overcome this limitation, extensive training and instruction on the use of the curriculum materials was provided to teachers and agreements of compliance (Appendix D) were signed and collected from teachers administering the experimental treatments.

Upon selection as a site for this study, teachers were provided with a link to a video description of the study. This six minute video highlighted the important components of the study, especially the importance of teaching the units according to the daily lesson plans and following the sequence of instruction exactly. Following the video training, and prior to beginning the treatment, each of the teachers met with me in person to receive curriculum materials and discuss the curricula in detail. Each day of instruction was discussed, including the intended flow, lesson plan format, activities, and intended instructional methods. Personal instruction lasted between 45 minutes and an hour for each teacher. At the completion of the face-to-face training, teachers signed agreements of compliance. Continued contact and support was available for teachers if problems arose during the instruction of the experimental treatment units, and constant

contact was maintained between sure teachers and the research team during the experimental treatment window.

### **Procedures**

This quasi-experiment was conducted in the fall semester of 2015. Data were collected in two phases: collection of student characteristics, and collection of STEM assessment knowledge. The first phase of data collection was the collection of information related to participant demographic and classification variables. Each teacher participating in this study collected information from school databases related to student socioeconomic status, as determined by eligibility for free and/or reduced lunch, and learning disability, as classified by presence of an Individualized Educational Plan (IEP). This information was compiled by teachers and reported on an encrypted excel spreadsheet along with a unique participant identifier which allowed students to be anonymously tracked through the research study. For two of the sites, information regarding free and reduced lunch status was not readily available to the teachers. In these cases, information was gathered by contacting an appropriate representative within the school district who could provide the SES classification for each student in the study.

The use of the *KLSI v. 3.1* in this study was guided by a research grant. The granting entity required one of the researchers on this project to administer and maintain control of the assessments. To accomplish this, I traveled to each school and administered the paper version of the *KLSI v. 3.1* to students. Students included their unique identifier on their *KLSI* instruments, to protect confidentiality, instruments were coded using an excel formula and entered in to the encrypted spreadsheet.

The final phase of data collection was completed by the agriculture teachers who participated in the study. Prior to teaching each unit, teachers administered a pretest, and at the completion of each unit of experimental curricula, a posttest was administered. These assessments included no names, only the unique identifier for each students, and were hand-scored once by the teacher according to the predefined answer key, then again by the research team to ensure scoring was both consistent between teachers and correct. Scores on the pre and posttests were added to the encrypted spreadsheet.

### **Population and Sample**

This study included participants from Principles of Agriculture, Food, and Natural Resources classes in the state of Texas. This section will outline the selection and recruitment for sites, along with descriptions of sites and participants.

#### *Sampling Procedure*

Sites were recruited through purposive selection based on the diversity of school population, regional differences, location in relation to Texas A&M University, and teacher qualities including commitment to project and teaching history. According to Frankel, et. al. (2006) the use of purposive sampling is sometimes necessary in quasi-experimental educational research due to the need for collaboration between researchers and teachers, administrators, and school districts. Twelve sites were identified through this process as viable locations for experimental testing. Of these sites, four failed to receive authorization at the district level, two had scheduling issues which prevented them from completing the study in the Fall 2015 semester, and one failed to respond. The resulting five schools received proper site authorization and continued with the

study. Due to extenuating circumstances, one of the sites beginning the experimental treatment was unable to complete the study within the time allowed, and data from this school were excluded from analyses. The final population included students enrolled in the Principles of Agriculture, Food, and Natural Resources classes at four high schools in Texas,  $N = 128$ .

According to Hair (2010), the minimum sample size required for statistical analysis using a MANOVA is  $n = 20$  per group. While only two experimental treatments were included in this study, classification of multiple subgroups based on independent variables led to the potential for more groups. Mortality in educational research has been estimated to be as high as 50% (Jurs & Glass, 1971), however studies using intact agricultural education classrooms reported mortality rates at or below 40% (Myers, 2004; Thoron & Myers, 2012). To account for loss of participants, sample size was adjusted to account for potential subject mortality and absences. Jurs and Glass (1971) suggest omitting data in classroom settings from individuals who miss more than 20% of test instruction, and suggested an increase in sample size by 25% to account for this potentially eliminated data. Based on these factors, a desired number of students to enroll in the study was set at  $N = 100$ . At the completion of the study, complete data and consent documentation was collected from  $n = 121$  students.

### *Consent*

According to the Texas A&M University Institutional Review Board (IRB), all human subjects in research are required to consent to participation. Special considerations are required when working with vulnerable populations, including

minors. This study began, as required, with completion of an application through the Texas A&M IRB. The IRB approved this research (Appendix E), granting approval for this study with minors in the presence of both parental consent and student assent, along with a site authorization completed for each of the participating schools. The documents associated with consent can be found in Appendices F and G. Teachers were sent electronic copies of the parental consent form to print and send home with students at least two weeks prior to the beginning of the experimental curriculum. Student assent was also required for this study. On the site visit to administer the KLSI inventory, student assent letters (Appendix G) were distributed and collected.

Data from students not completing the consent or assent process, those missing more than 20% of the instructional days per unit, or those missing pre or post test data for either unit accounted for the loss of  $n = 7$  students from data analysis. The number of students beginning and completing the study is shown in Table 11.

Table 11

*Students Enrolled and Completing Study by Site*

Site	Students Enrolled		Students Completed	
	<i>f</i>	%	<i>f</i>	%
1	18	100.0	18	100.0
2	44	100.0	37	84.1
3	34	100.0	31	91.2
4	41	100.0	35	85.4
Total	128	100.0	121	94.5

### *Description of Participants*

In quasi-experimental research, providing information related to the similarities and differences of non-equivalent groups can provide information for rational comparisons of data (Shadish, et. al., 2002). To allow for an examination of the school, teacher, and student factors which were not classified as independent variables in this study, this section will provide information related to the sites, teachers, and students included in this study.

#### **Site Descriptions**

Participants included in the final analysis were located at four public high schools in Texas. Data regarding the four schools used in this study were collected from the Academic Excellence Indicator System (AEIS) available through the Texas Education Agency. Information was gathered based on the 2014-15 school year reporting cycle, which was the most recent year available. Table 12 shows a comparison of selected school characteristics for the four sites.

There was, as expected, variation in schools participating. Two of the sites were small schools in rural communities, while site three and four were schools located in urban areas with higher enrollment. All of the sites had a lower percentage of Hispanic students than the Texas average, which was to be expected in the geographic area, as they were located further from the Southern border than many other Texas schools. Site three showed notable differences from the other sites in the percentage of students with low SES classification. Descriptions of the specific students participating in this study are discussed later in this section.



Table 12

<i>Descriptions of Schools Participating in Study</i>					
Characteristic	Site 1	Site 2	Site 3	Site 4	State
2015 Accountability Rating	Met Standard	Met Standard	Met Standard	Met Standard	--
Enrollment	606	202	1732	1599	--
Ethnic Distribution %					
African American	9.7	11.9	13.6	23.2	12.6
Hispanic	23.1	32.7	22.5	46.1	52.0
White	64.0	53.0	51.1	29.4	28.9
American Indian	0.3	0.0	0.3	0.1	0.4
Asian	0.2	0.0	8.6	0.3	3.9
Pacific Islander	0.0	0.0	0.0	0.1	0.1
Two or More Races	2.6	2.5	3.8	1.0	2.0
Low SES %	36.0	39.1	33.3	64.8	58.8
At-Risk %	46.7	37.6	30.4	35.2	51.2
Special Education Graduates %	14.1	20.0	4.2	7.5	--

### Teacher Descriptions

Students within each of the treatment groups were instructed by teachers with varying time and background information. Information related to the teachers participating in this study is included in Table 13.

It is important to note the teacher differences and similarities as potential extraneous variables related to the findings of this study. Being aware of this information allowed research to be conducted keeping in mind teacher differences as potential explanations for findings. The teacher showing the most difference from the others was at site one. This teacher had much more experience and a higher level of

education than the other three teachers. Site one was randomly assigned as the control group, and the teacher did not instruct any of the experimental curricula. This allowed teacher differences to be minimized with regard to the differences between the teacher at site one and the other three instructors. Awareness of alternative explanations for findings in quasi-experimental research is a hallmark of quality study design (Shadish, et al., 2002).

Table 13

<i>Teacher Characteristics</i>				
Characteristic	Site 1	Site 2	Site 3	Site 4
# Agriculture Teachers in Dept.	3	3	3	4
Education Completed	M.S.	B.S.	B.S.	B.S.
Years Teaching	31	9	7	3
Postsecondary Soils Classes Taken	1	1	1	1
Postsecondary Water Science Classes Taken	0	0	0	0
Chemistry Classes Taken in Undergraduate Program	1	2	0	0

### **Participant Descriptions**

School and teacher factors in this study play a secondary role to the characteristics of individual students participating in the experimental treatments. A total of  $n = 121$  students were enrolled in the Principles of AFNR courses at the selected study locations and completed the entire study, which included instruction in both rounds of treatment, the consent process, and the availability of demographic information.

Although demographic data including gender and ethnicity were not included in the analysis related to the research question, this information can still provide insight into the overall makeup of each test site. Gender and ethnic distribution of each of the sites can be found in Table 14.

Table 14

*Demographic Information of Participants*

Characteristic	<u>Site 1</u>		<u>Site 2</u>		<u>Site 3</u>		<u>Site 4</u>		<u>Total</u>	
	<i>f</i>	%	<i>F</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%
Gender										
Male	11	61.1	19	51.4	18	58.1	14	40.0	62	51.2
Female	7	38.9	18	48.6	13	41.9	21	60.0	59	48.8
Ethnic Distribution										
White-non-Hispanic	12	66.7	15	40.5	14	45.2	17	48.6	58	47.9
Hispanic	3	16.7	14	37.8	9	29.0	12	34.3	38	31.4
Black	3	16.7	6	16.2	8	25.8	5	14.3	22	18.2
Asian	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Native American	0	0.0	0	0.0	0	0.0	1	2.9	1	0.8
Pacific Islander	0	0.0	0	0.0	0	0.0	0	0	0	0.0
Two or More Races	0	0.0	2	5.4	0	0.0	0	0	2	1.7

Note: due to rounding, all values for a site may not equal 100%

Information was also gathered related to the independent variables of interest in this study. This information included learning style as determined by *KLSI* instrument, classification of low SES as determined by free/reduced lunch classification, and learning disability status, as classified by presence of an IEP. Descriptions of participants as classified on independent variables is shown in Table 15.

Table 15

*Descriptions of Independent Variable Characteristics by Site*

Characteristic	<u>Site 1</u>		<u>Site 2</u>		<u>Site 3</u>		<u>Site 4</u>		<u>Total</u>	
	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%	<i>f</i>	%
SES										
Low SES	6	33.3	18	48.6	8	25.8	20	57.1	52	43.0
Normal SES	12	66.7	19	51.4	23	74.2	15	42.9	69	57.0
Learning Disability										
IEP	5	27.8	7	18.9	13	41.9	10	28.6	35	28.9
No-IEP	13	72.2	30	81.1	18	58.2	25	71.4	86	71.1
Grasping Preference										
Apprehension (CE)	10	55.6	30	81.1	18	58.1	27	77.1	85	70.2
Comprehension (AC)	8	44.4	7	19.9	13	41.9	8	22.9	36	29.8

After calculating the *KLSI* style for each of the participants, and examining the resulting number of students within each of the learning styles, it was determined to condense the number of learning styles classified to maintain group sizes large enough for statistical analysis. Students learning styles were examined in relation to the prehension dimension, and classified as either having a learning style showing preference for grasping experience through apprehension (CE) or comprehension (AC).

### Data Analysis

Analyzing the data collected through this experiment was based on data analysis procedures related to determining statistical and practical differences with regard to answering the research question. The correct statistical tools are required in order to complete any analysis and accurately interpret data (Meyers, et. al., 2012). All data collected through this treatment were compiled in a MS Excel worksheet and analyzed using IBM © SPSS version 23.

This section will outline the procedures for selecting and validating the assumptions of statistical tools, along with outlining procedures for determining statistical and practical differences in data.

### *Determining Statistical Significance*

A multivariate analysis of data was determined to be the optimal statistical tool for interpreting information from this study (Meyers, et. al., 2012; Stevens, 2009). There are several reasons why using a multivariate approach was most desirable in this situation. First, the classification of variance on multiple dependent variables reduces the potential for committing a Type I error during analysis. Second, the factors of learning are likely to have interaction, which is not accounted for in a univariate analysis. Finally, as there are multiple factors at play in this study, with a high likelihood of correlation and interaction, a multivariate approach was more likely to differentiate between true effects in the analysis (Meyers, et. al., 2012; Tabachnick & Fidel, 2007).

This study allowed for an examination of multiple factors related to student cognition and the understanding of abstractions. As such, a multivariate approach to the experimental design may allow for greater statistical power in examination of the variables (Meyers, et. al., 2013). The important factors in the decision for conducting a multivariate analysis over a univariate analysis include that many experimental treatments are likely to affect the study participants in more than one way, and using multiple criterion gives a more detailed description of the factor being investigated (Stevens, 2009).

To establish data analysis procedures *a priori*, procedures were written prior to collecting data. To determine differences, a two-way MANOVA would be evaluated as a potential analysis tool. If the assumptions of MANOVA were met, the statistical analysis would be completed using the change in scores from pretest to posttest for both the water science unit and soil science unit as the outcome variables and preference for apprehension or comprehension, socioeconomic status, learning disability classification, and sequence of instruction as the fixed factors. According to Stevens (2009), a two-way MANOVA design is appropriate in cases where research questions indicate a desire to understand if there is an interaction between independent variables and multiple dependent variables.

As this study was examining two different units of instruction and using the change ( $\Delta$ ) between pretest and posttest as the outcome variable as suggested by Tabachnick & Fidel (2007), it was determined that a two-way MANOVA was more appropriate for analysis than a split-plot factorial (SPF) MANOVA.

There are four assumptions which must be met when using MANOVA (Meyers, et. al., 2013). These assumptions include:

- The response (dependent) variables are continuous
- The residuals follow the multivariate-normal probability distribution with means equal to zero.
- The variance-covariance matrices of each group of residuals are equal.
- The individuals are independent.

In this study, the dependent variables met the first assumption and were continuous. To determine if the residuals followed a multivariate normal distribution, Malhalinobis'  $D^2$  was calculated and used as the factor for determining if outliers posed a threat to the omnibus MANOVA analysis.

To determine if the variance-covariance matrices of each group of residuals were equal, Box's  $M$  statistic was calculated. According to many statisticians, Box's  $M$  statistic is too conservative an estimate to use in most analyses in social sciences (Mayers, 2013; Meyers, et. al., 2013; Tabachnick & Fidel, 2007). Mayers (2013) stated "if sample sizes are equal, MANOVA has been shown to be robust (in terms of type I error) to violations even with a significant Box's  $M$  test" (p. 329).

Meyers et. al. (2013) pointed out two drawbacks to using MANOVA. These drawbacks include issues when variables are relatively uncorrelated, and in cases where multicollinearity exists. These drawbacks were addressed in relation to data prior to analysis. The first drawback of MANOVA occurs when dependent variables are not relatively correlated (Meyers, et. al., 2013). To determine that the dependent variables reached a minimum level of correlation, Bartlett's Test of Sphericity was used.

According to Meyers, et. al. (2013) the use of Bartlett's test allows for confirmation that the variables are sufficiently correlated for a multivariate analysis. Violation of this assumption poses the greatest risk to committing a Type I error in a multivariate analysis (Tabachnick & Fidel, 2007). A determination was made that should a significant ( $p < 0.001$ ) result on Barlett's test be determined, we would proceed with the multivariate analysis. If Barlett's test was not significant, we would analyze

each of the dependent variables using univariate ANOVAs with an adjusted alpha level to avoid alpha-level inflation, per the recommendation of Tabachnick and Fidel (2007).

The next drawback of using MANOVA is that it is not appropriate to use when multicollinearity exists. Meyers, et. al. (2013, pp. 228-229) states, “multicollinearity occurs when some dependent variables in combination perfectly or almost perfectly predict another dependent variable.” To assure that multicollinearity was not an issue, the multicollinearity function in IBM SPSS was used.

Initial data analysis began with conducting an omnibus multivariate analysis in IBM SPSS and examining the homogeneity tests to determine if assumptions related to MANOVA were met. If the assumptions were not violated, the results of the omnibus MANOVA would be examined to determine if there was a statistically significant interaction in the multivariate data. Significance was deemed enough to reject the null hypothesis at the  $\alpha = .05$  level (Meyers, et. al., 2013). Following the verification of assumptions, the procedures for analyzing data were set using the following parameters: if statistical significance was found, we would first examine any significant two-way interaction between dependent variables by exploring the univariate interaction effects that composed it (Meyers et. al., 2013). For each of the statistically significant univariate interactions, we would perform an analysis of the simple main effects and interpret results for the dependent variable, using an alpha level adjusted to  $\alpha = 0.02$  as suggested by Bonferroni, to prevent an escalating alpha level with multiple dependent variables (Meyers, et. al., 2013).



Following examination of omnibus multivariate interactions, we would then follow by examining the univariate main effects for those dependent variables that were not involved in the significant interaction (Meyers, et. al, 2013). For each univariate effect not included in the significant interaction, we would interpret the results of those comparisons again using a Bonferroni adjustment for two dependent variables, yielding an alpha level of  $\alpha = 0.03$  for decisions of significance. Upon discovery of a significant difference in a univariate main effect, we would perform multiple comparison tests and interpret the results.

Special attention to the use of MANOVA in a crossover design was discussed by Tabachnick and Fidel (2007). Because of the variation in treatment across measures, it was recommended to be mindful of proceeding with a MANOVA when the assumptions were violated, as the results may not be based on true interaction, but rather the effects of crossing treatments. To account for this, should the assumptions of MANOVA be violated, the decision would be made to examine the two units of instruction separately using two univariate ANOVAs (Howell, 2012; Mayers, 2013; Tabachnick & Fidel, 2007). In this case, the resulting univariate analysis would yield two ANOVAs from the same data set. Per the recommendation of Stevens (2009), the alpha level for significance should be adjusted in cases where multiple calculations are used to prevent the risk of committing a Type I Error. The most widely accepted method for adjusting the alpha level is to use Bonferroni's adjustment (Meyers, et. al., 2013; Stevens, 2009; Tabachnick & Fidell, 2007). The resulting level for determining statistical significance in this case would be  $p < 0.02$ .

### *Determining Practical Significance*

Stevens (2009) warns that determining statistical significance may not be sufficient to report true differences in data. Because of this, the importance of determining practical significance, which is more commonly referred to as effect size, is also critical to data analysis. Effect size is an estimate of the magnitude of the group differences in the population (Stevens, 2009), and reporting effect size is “critical in conducting quality analyses of data related to comparing group means” (Tabachnick & Fidel, 2007, p. 54). In a univariate analysis of variance, the most appropriate calculation for effect size is based on an examination of the explained and unexplained variance (Wilk’s lambda) in the population. This study used partial eta squared ( $\eta_p^2$ ) as the measure for reporting effect size. Cohen (1977) established guidelines for determining practical significance using  $\eta_p^2$ . According to Cohen (1977) effect sizes should be considered small at  $\eta_p^2 = 0.01$ , medium at  $\eta_p^2 = 0.06$ , and large at  $\eta_p^2 = 0.14$ .

### **Threats to Validity**

As explained in Shadish, et. al. (2002) “threats to validity are specific reasons why we can be partly or completely wrong when we make an inference about covariance, about causation, about constructs, or about whether the causal relationship holds over variations in persons, settings, treatments, and outcomes” (p. 39). They continue by saying “these threats serve a valuable function: they help experimenters to anticipate the likely criticisms... so the experimenter can rule them out” (p. 40). With any research in education, there are likely to be factors which limit the overall validity of the results (Ary, Jacobs, Sorenson, & Walker, 2013; Frankel, et. al., 2012).

This section will provide information about the methods taken during study design and administration which were taken to mitigate the threats on the four types of validity: statistical conclusion, internal, construct, and external (Shadish, et. al., 2002).

### *Statistical Conclusion Validity*

Statistical conclusion validity includes “reasons why inferences about covariation between two variables may be incorrect” (Shadish, et. al., 2002, p. 45). Among these threats are low statistical power, violated assumptions of statistical tests, unreliability of treatment implementation, and extraneous variance in the experimental setting.

To mitigate these factors, several design features were included. First, the issue of low statistical power was addressed by adhering to the guidelines of Cohen (1988) in interpreting and Wilkinson (1999) for reporting effect sizes and power with all statistical analyses. According to Meyers et. al. (2013), “larger effect sizes are associated with greater levels of power” (p. 35). To account for the threat of violated assumptions, carefully outlined plans for analyzing data were established *a priori*, including information related to adjustments should assumptions be violated. The unreliability of treatment implementation was addressed through careful training of teachers administering the experimental curricula, and through exclusion of data from students missing more than 20% of the instruction in any one experimental unit. Finally, it was known that extraneous variance may be a factor in this study. Site and teacher differences are discussed earlier in this chapter and careful consideration was taken in data interpretation to account for extraneous variables beyond the control of this quasi-experiment.

### *Internal Validity*

Internal validity refers to “inferences about whether observed covariation between A and B reflects a causal relationship from A to B in the form in which the variables were manipulated or measured” (Shadish, et. al., 2002, p. 53). Threats to internal validity include: temporal precedence, selection, history, maturation, regression, attrition, testing, and instrumentation (Campbell & Stanley, 1963; Shadish, et. al., 2002)

The use of the crossover design mitigated most of the threats to internal validity (Campbell & Stanley, 1963). By allowing groups to experience both treatments, in differing cognitive sequences and with differing content, the threats of temporal precedence, history, and maturation were eliminated or greatly reduced (Campbell & Stanley, 1963). The use of repeated measures is a method to control for regression, along with the selection of participants based on site, rather than assignment to a group based on prior scores. Attrition was addressed through eliminating incomplete scores from data analysis. To account for threats from testing, the order of the questions on the pre and post tests used as assessments for the water and soil science units were switched. Using an identical instrument was implemented through the recommendation of Shadish, et. al. (2002) as a means for controlling for threats to internal validity based on instrumentation.

### *Construct Validity*

“Construct validity involves making inferences from the sampling particulars of a study to the higher-order constructs” (Shadish, et. al., 2002). Because of the nature of this study and its relationship to STEM concepts present in test curriculum, the

examination of construct validity was conducted by the panel of experts who examined the unit assessments. To establish the content and face validity of the unit exams, Crestwell (2008) suggested review by a panel of experts. University teacher educators, secondary agricultural educators, and curriculum development faculty at Texas A&M determined the content and face validity of the unit assessments to be acceptable.

### *External Validity*

Threats to external validity include “reasons why inferences about how study results would hold over variation in persons, settings, treatments and outcomes may be incorrect” (Shadish, et. al., p. 87). It is important to note the intent of this study as an exploratory examination of the factors related to cognitive sequencing of units in agricultural education courses. According to Rosenbaum (2008), external validity is rarely the sole focus of an exploratory examination, rather the intent is to gather data which may be able to provide guidance for further examination of the topic.

Such threats to external reliability include the interaction of the causal relationship with units, treatment variations, outcomes, settings, and context-dependent mediation. The crossover design was critical in controlling for most of these threats, as the same treatments were applied to participants in each of the treatment units and settings. Although efforts were made to minimize treatment variations, it is important to note when generalizing these findings that differences between teachers and school settings did exist which could not be controlled for as a function of this study design. In addition, the use of water and soil science as the context with which to deliver science concepts should be noted as a context-dependent measure of the effects of cognitive

sequencing, and variation may exist should other contexts be used for an examination of this topic.

### **Summary**

This study was designed to determine if differences existed in student performance on science content assessments between or within groups based on the independent variables of learning style, socioeconomic status, learning disability classification, and sequence of instruction. This section outlined the design of the study and experimental curricula, along with the procedures, population, and description of both the participants and data analysis. Finally, this chapter explained the procedures for analyzing data determined prior to data collection, and the efforts made to mitigate threats to validity.

This quasi-experiment utilized a crossover design to allow each student to experience both sequences of instruction. The experimental curricula was developed to purposively sequence each new concept beginning with either apprehension (CE) or comprehension (AC) type activities. One unit in soil science and one unit in water science were created in each of the sequences, resulting in four experimental curriculum units. Groups of students from four sites were randomly assigned to one sequence for the water science unit and the opposite sequence for the soil science unit. Teachers received specific training related to the instruction of the units, with special attention given to the sequence of each lesson. The *KLSI* was administered to each student, along with collecting demographic information related to socioeconomic status and learning disability classification.

As information from two dependent variables was collected, the determination was made to utilize a MANOVA for data analysis, provided the data were consistent with the assumptions of a MANOVA for comparison of means. After testing the assumptions related to MANOVA, the dependent variables were found insufficiently correlated to appropriately use a MANOVA, and the data analysis proceeded using the separate ANOVAs as outlined in this section (Meyers, et. al., 2013). The next chapter will discuss the findings related to both statistical assumptions and the data related to the independent variables and outcome variables.

## CHAPTER IV

### FINDINGS

Agricultural education has been seen as a viable platform for delivering STEM content (Myers & Dyer, 2004). Although agricultural educators are aware of the expectation to incorporate STEM concepts into their courses, little research has been conducted on the most effective ways to teach STEM concepts (Stone, 2011).

Agricultural education is rooted in experiential learning (Baker, et. al., 2012; Knobloch, 2003; Roberts, 2006; Smith, et. al., 2015). This research study was designed to examine effective methods for teaching STEM concepts in agricultural education courses within the framework of Kolb's (1984, 2015) experiential learning theory, by examining the effects of sequencing the prehension dimension of grasping experience.

To fulfill the purpose of this study, the research was guided by the following research question:

1. What interactions exist between the factors of cognitive sequence, learning style, socioeconomic status, and learning disability on student performance on STEM content assessments in agricultural education?

This research question yielded a null and alternative hypothesis for testing:

- H<sub>0</sub>1:        There is no interaction between cognitive sequence, learning disability, socioeconomic status and learning style on STEM-based content assessment performance in agricultural education when cognitive sequence is manipulated.



H<sub>A1</sub>: Interaction exists between cognitive sequence, learning disability, socioeconomic status and learning style on STEM-based content assessment performance in agricultural education when cognitive sequence is manipulated.

This chapter will outline the findings from this study in regard to the research research question, along with providing evidentiary support for the statistical analysis of data.

### **Findings Related to Statistical Assumptions and Analysis**

Prior to examining the findings related to the research question, an examination of the data in relation to the assumptions of using a two-way MANOVA was conducted. This examination allowed for a comprehensive evaluation of the dependent variables in relation to their correlation and the equality of the variance-covariance matrices. The four assumptions that need to be met when conducting a MANOVA are (Meyers, et. al., 2013):

1. The response (dependent) variables are continuous.
2. The residuals follow the multivariate-normal probability distribution with means equal to zero.
3. The variance-covariance matrices of each group of residuals are equal.
4. The individuals are independent.

Based on the statistical analysis procedures determined in Chapter Three, the first step in analyzing the data was to determine if the statistical assumptions for using a MANOVA in data analysis were violated. The first assumption of MANOVA is the

requirement for continuous dependent variables. This assumption was true for all test data related to the dependent variables of change in score on each of the units of instruction. With regard to the fourth assumption, the individuals in this study were independent, in that they only had scores for each test once, and belonged to separate treatment groups with regard to cognitive sequence of instruction.

To test the assumption that the residuals follow a multivariate normal probability distribution, Box'  $M$  coefficient was calculated. The results of this test yielded significance at the  $p = 0.001$  level. There are several explanations for this violated assumption. First, there could have been an issue with the crossover design and/or control lending differences to the covariance matrix, the unequal group sizes may have also played a role in the difference. Alone, a violation of this assumption would not lend support for a different statistical analysis, as MANOVA has been shown to be robust even in cases where this assumption is violated (Meyers, et. al., 2013, Tabachnick & Fidel, 2007).

To examine the assumption that the residual covariance matrix was proportionate to an identity matrix, Bartlett's Test of Sphericity was performed. According to Meyers, et. al. (2013), a statistically significant result on this test is required to determine that the dependent variables are sufficiently correlated to proceed with the analysis. The resulting analysis yielded non-significant ( $p = 0.52$ ) results. This result, combined with the violation noted above, led to the decision to use two univariate ANOVAs to answer the research question.

The resulting statistical analysis included running two separate two-way ANOVAs, using the dependent variable of change in score from pretest to posttest and the independent variables of cognitive sequence, learning style, socioeconomic status, and learning disability for both the water science unit and the soil science unit. Per the suggestion of Tabachnick & Fidel (2007), the adjusted alpha level for determining significant differences with two univariate ANOVAs was set using a Bonferroni adjustment at  $\alpha = 0.02$ . To ensure the assumption of homogeneity of variances was not violated through the univariate analysis, Levene's test was conducted. The resulting values were insignificant for the analysis of change from pre to post test score for both the water science  $p = 0.12$  and soil science  $p = 0.08$  assessments

### **Findings Related to Pre and Posttest Comparison of Sites**

Prior to analyzing the results related to the research question, data were analyzed to compare the means and spread of sites on the pretest measures. Because different sites were used, with differing teacher and school factors, an initial examination of prior knowledge was determined to be necessary to interpret subsequent differences which may exist based on the independent variables.

#### *Pretest Comparisons of Sites*

An ANOVA was used to determine if statistically significant differences existed in the four test sites on the pretest measures. No significant differences ( $F(3,117) = 1.22, p = 0.30, \eta_p^2 = 0.03$ ) were found in the pretest water science assessment scores between students at the sites, as shown in Tables 16 and 17.

Table 16

<i>Descriptive Statistics for Pretest Scores on Water Science Unit Assessment by Site</i>						
	<i>n</i>	<i>M</i>	<i>SD</i>	<i>SE</i>	Min	Max
Site 1	18	23.11	17.66	4.31	0	53
Site 2	37	22.95	19.86	3.00	0	76
Site 3	31	24.87	22.25	3.28	0	82
Site 4	35	16.86	11.76	3.09	1	53
Total	121	21.94	18.32	1.73	0	82

Table 17

<i>Comparative Analysis of Pretest Scores on Water Science Unit Assessment by Site</i>							
	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>	$\eta_p^2$	1- $\beta$
Between Groups	1225.85	3	408.62	1.22	0.30	0.03	0.32
Within Groups	39059.44	117	333.84				
Total	97276.00	121					

In addition to the comparison of pretest assessments on the water science unit, pretest comparisons were calculated for the soil science unit. The ANOVA revealed statistically significant differences ( $F(3,117) = 5.10, p = 0.02, \eta_p^2 = 0.15$ ) in the means between sites on the soil science pretest assessment, as shown in Tables 18 and 19.

Table 18

<i>Descriptive Statistics for Pretest Scores on Soil Science Unit Assessment by Site</i>						
	<i>n</i>	<i>M</i>	<i>SD</i>	<i>SE</i>	Min	Max
Site 1	18	18.61	15.79	3.63	1	62
Site 2	37	20.41	16.29	2.53	2	67
Site 3	31	27.68	19.59	2.77	0	68
Site 4	35	12.89	8.55	2.61	0	33
Total	121	19.90	16.19	1.46	0	68

Table 19

<i>Comparative Analysis of Pretest Scores on Soil Science Unit Assessment by Site</i>							
	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>	$\eta_p^2$	$1-\beta$
Between Groups	3635.84	3	1211.95	5.10	0.02	0.15	0.91
Within Groups	27801.51	117	237.62				
Total	79001.00	121					

Post hoc analysis revealed the differences in between group pretest scores on the soil science assessment were due to differences ( $p = 0.01$ ) between site three and four. The nature of this study allowed for an examination of change from pretest to posttest (Shadish, et. al., 2012), and as such, the differences in pretest scores were determined as no threat to the analysis of findings related to the question of interest, but were noted for examination in the outcomes of hypothesis testing.

#### *Posttest Comparisons of Sites*

Following completion of both units of instruction, data were compared by site on the posttest measures for both the water science and soil science unit, to determine what differences existed based on site which may account for any error variance in the examination of the independent variables present in the research question.

The results of the comparison of means on posttest assessments in the water science unit are shown in Tables 20 and 21.

Differences between sites were expected, as site one was the control and received no instruction in water science between pre and posttest measures. Multiple comparisons of means following the significant omnibus ANOVA revealed significant

differences ( $F(3,117) = 20.81, p = 0.01, \eta_p^2 = 0.35$ ) between site one (control) and the three other sites in the study. No other significant differences between groups were found.

Table 20

*Descriptive Statistics for Posttest Scores on Water Science Unit Assessment by Site*

	<i>n</i>	<i>M</i>	<i>SD</i>	<i>SE</i>	Min	Max
Site 1	18	23.44	16.13	5.28	3	52
Site 2	37	66.89	18.62	3.68	30	99
Site 3	31	73.32	30.33	4.02	2	100
Site 4	35	60.29	20.43	3.79	21	100
Total	121	60.17	27.39	2.12	2	100

Table 21

*Comparative Analysis of Posttest Scores on Water Science Unit Assessment by Site*

	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>	$\eta_p^2$	1- $\beta$
Between Groups	31312.77	3	10437.59	20.81	0.01	0.35	1.00
Within Groups	58681.93	117	501.56				
Total	527998.00	121					

The posttest comparison of means on soil science units by site was also conducted. Results of this examination are shown in Tables 22 and 23.

Table 22

*Descriptive Statistics for Posttest Scores on Soil Science Unit Assessment by Site*

	<i>n</i>	<i>M</i>	<i>SD</i>	<i>SE</i>	Min	Max
Site 1	18	19.67	15.70	4.72	3	61
Site 2	37	76.97	15.89	3.29	30	98
Site 3	31	61.48	23.99	3.60	20	97
Site 4	35	71.66	21.96	3.39	22	99
Total	121	62.94	27.49	1.90	3	99

Table 23

<i>Comparative Analysis of Posttest Scores on Soil Science Unit Assessment by Site</i>							
	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>	$\eta_p^2$	$1-\beta$
Between							
Groups	43717.99	3	14572.67	36.31	0.01	0.48	1.00
Within							
Groups	46958.60	117	401.36				
Total	570044.00	121					

As with the water science unit, differences ( $F(3,117) = 36.31, p = 0.01, \eta_p^2 = 0.48$ ) were observed in the omnibus ANOVA analysis. A post hoc comparison of the means for each group revealed expected differences between the control site (site one) and the other three sites ( $p = 0.01$ ). Significant differences ( $p = 0.11$ ) were also found between sites two and three. No significant differences were found between site four and sites two or three.

As the differences in scores from sites for each unit served as the dependent variables for the ANOVA analyses to answer the research question, site based differences in these gains were also examined. The resulting differences in the means of change from pretest to posttest for the water science unit are shown in Tables 24 and 25.

Table 24

<i>Descriptive Statistics for Change in Pre and Posttest Scores on Water Science Unit Assessments by Site</i>						
	<i>n</i>	<i>M</i>	<i>SD</i>	<i>SE</i>	Min	Max
Site 1	18	0.33	3.24	4.97	-7	6
Site 2	37	43.95	18.15	3.47	13	83
Site 3	31	48.45	31.04	3.79	2	92
Site 4	35	43.43	18.04	3.56	14	95
Total	121	38.46	26.34	1.99	-7	95

Table 25

*Comparative Analysis of Change in Pre and Posttest Scores on Water Science Unit Assessments by Site*

	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>	$\eta_p^2$	1- $\beta$
Between Groups	31237.94	3	10412.65	23.43	0.01	0.38	1.00
Within Groups	52004.14	117	444.48				
Total	262248.00	121					

Differences in scores did exist ( $F(3,117) = 54.54, p = 0.01, \eta_p^2 = 0.58$ ). The change in score was expected to be different ( $p = 0.01$ ) for the control group (site 1), and the analysis supported this expectation. An examination of the simple main effects related to the change in pre and posttest scores revealed that significant differences existed only between the control site and the other three sites ( $p = 0.01$ ), no significant differences were found in gains between students at the three experimental sites.

It is interesting to note that there were no posttest scores lower than the pretest score for any student at sites receiving experimental treatments, although many of the students still exhibited final scores on the assessment which were well below an 80% mastery when the global score rather than change scores were examined. There were six students in the control group whose posttest scores were lower than their pretest scores on the water science unit.

The comparison of means for the change in scores from pre to posttest measure was also calculated for the soil science unit. The results of this comparison are shown in Table 26 and Table 27.



Table 26

*Descriptive Statistics for Change in Pre and Posttest Scores on Soil Science Unit Assessments by Site*

	<i>n</i>	<i>M</i>	<i>SD</i>	<i>SE</i>	Min	Max
Site 1	18	1.06	2.55	4.11	-3	6
Site 2	37	56.57	17.44	2.87	25	90
Site 3	31	33.81	16.87	3.13	8	74
Site 4	35	58.77	21.70	2.95	14	95
Total	121	43.12	26.67	1.65	-3	95

Table 27

*Comparative Analysis of Change in Pre and Posttest Scores on Soil Science Unit Assessments by Site*

	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>	$\eta_p^2$	1- $\beta$
Between Groups	49803.35	3	16601.12	54.54	0.01	0.58	1.00
Within Groups	35613.04	117	304.39				
Total	310351.00	121					

There was a difference ( $F(3,117) = 54.54$ ,  $p = 0.01$ ,  $\eta_p^2 = 0.58$ ) found between groups for change in pretest to posttest score by site. Post hoc analysis of the simple main effects for site revealed differences ( $p = 0.01$ ) between the control group and all three experimental groups, as would be expected based on the study design. A comparison of the simple main effects also revealed differences between site three when compared to site two ( $p = 0.01$ ) and site four ( $p = 0.01$ ). Site three showed a mean change in score on the soil science unit more than 20 points lower than the other two groups, the large standard deviation for this site is also worth noting in light of this result.

Looking at the observed differences in the means for pre and posttest measures by site provided background information related to student baseline knowledge scores, and knowledge gains in both water and soil science based on school and teacher factors. After examining findings related to comparison of groups by site, an examination of the research question could proceed.

### **Findings Related to the Research Question**

The research question in this study posed the query “What interactions exist between the factors of cognitive sequence, learning style, socioeconomic status, and learning disability on student performance on STEM content assessments in agricultural education?”

The research question was guided by the following null and alternate hypotheses:

H<sub>O</sub>1:        There is no interaction between cognitive sequence, learning disability, socioeconomic status and learning style on STEM-based content assessment performance in agricultural education when cognitive sequence is manipulated.

H<sub>A</sub>1:        Interaction exists between cognitive sequence, learning disability, socioeconomic status and learning style on STEM-based content assessment performance in agricultural education when cognitive sequence is manipulated.

To determine what interactions exist between the dependent variables of change in score on STEM content assessments and the independent variables of interest, the means of the change in scores for each of the units of experimental curriculum were

compared using two separate two-way ANOVAs. This analysis allowed for an omnibus ANOVA to determine if significant differences were observed between groups, and the examination of interaction effects between independent variables.

### *Description of Means by Group*

To begin the analysis, the descriptive results of change from pretest to posttest on both the water science and soils science unit assessments was calculated. The resulting descriptive data are reported in Table 28.

Table 28

#### *Means and Standard Deviations of Change in Score for Water Science and Soil Science Units by Independent Variable Group*

Variable	Category	Water Science Unit		Soil Science Unit	
		<i>n</i>	<i>M(SD)</i>	<i>n</i>	<i>M(SD)</i>
Grasping Preference	Apprehension	85	41.82(24.57)	85	47.69(26.62)
	Comprehension	36	30.53(28.93)	36	32.31(23.84)
Learning Disability	LD	35	40.77(27.04)	35	37.31(26.59)
	No LD	86	37.52(25.60)	86	45.48(26.51)
Socioeconomic Status	Low SES	52	40.58(23.65)	52	49.06(27.64)
	Not Low SES	69	38.46(26.34)	69	38.64(25.21)
Sequence of Respective Unit	AC to CE	72	43.69(17.97)	31	33.81(16.87)
	CE to AC	31	48.45(31.04)	72	57.64(19.52)
	Control	18	0.33(3.24)	18	1.06(2.56)

*Note:* The crossover design allowed for students receiving the water science unit in the AC to CE sequence to receive the opposite treatment for the soil science unit, which accounts for the differences in *n* between sequences

Following an analysis of the descriptive means, the means for each of the units of instruction were compared by using univariate analyses. Because of the nature of differences between the variance on the dependent variables, a multivariate analysis was not appropriate in this case.

### *Analysis of Interactions on Water Science Unit Assessments*

The results of difference between and within groups were calculated for the water science unit. The results of the omnibus ANOVA examination revealed significant differences ( $p \leq 0.02$ ) in the dependent variable. Significant differences were found for both preference for grasping experience ( $F(1,98) = 5.02, p = 0.02, \eta_p^2 = 0.05$ ) and cognitive sequence of instruction ( $F(2,98) = 31.29, p = 0.01, \eta_p^2 = 0.39$ ). These findings were superseded by the finding of a single statistically significant ( $F(2,98) = 17.96, p = 0.01, \eta_p^2 = 0.27$ ) interaction involving both preference for grasping experience and cognitive sequence. Based on the guidelines set forth by Cohen (1977), this difference had a large effect size  $\eta_p^2 \geq 0.14$ , and showed a high level of power. Based on the findings, the null hypothesis was rejected, and it was determined that interactions between cognitive sequence and preference for grasping experience did exist. Results of the omnibus ANOVA are shown in Table 29.

This significant interaction between cognitive sequence and learning style preference between apprehension and comprehension was examined through a test of the simple main effects for change in water science assessment score. Significant differences ( $p < 0.01$ ) were found based on the sequence of instruction.

Students whose preference for grasping information was through apprehension showed mean changes in score on the water science assessment 44.86 points higher than those who had a preference for grasping information through comprehension when the unit was presented in a cognitive sequence which began with a concrete experience. Students who were classified with a preference for grasping information through

comprehension showed mean differences in scores 16.31 points higher when the unit was presented beginning with abstract conceptualization.

Table 29

*ANOVA Table for the Effect of Learning Disability, Socioeconomic Status, Preference for Grasping Knowledge and Cognitive Sequence on Change in Pre and Posttest Scores on Water Science Unit Assessments*

	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>	$\eta_p^2$	1- $\beta$
Grasping	1500.72	1	1500.72	5.02	0.02*	0.05	0.60
LD	135.56	1	135.56	0.45	0.50	0.01	0.10
SES	7.06	1	7.06	0.02	0.88	0.00	0.05
Sequence	18709.17	2	9354.58	31.29	0.01*	0.39	1.00
Grasping*LD	44.41	1	44.41	0.15	0.70	0.01	0.07
Grasping*SES	64.05	1	64.05	0.21	0.64	0.01	0.07
Grasping*Sequence	10740.47	2	5370.23	17.96	0.01*	0.27	1.00
LD*SES	134.26	1	134.26	0.45	0.50	0.01	0.10
LD*Sequence	313.33	2	156.66	0.52	0.59	0.01	0.07
SES*Sequence	58.66	2	29.33	0.10	0.91	0.01	0.13
Grasping*LD*SES	10.87	1	10.87	0.03	0.85	0.01	0.05
Grasping*LD*Sequence	20.34	2	10.17	0.03	0.97	0.01	0.06
Grasping*SES*Sequence	338.09	2	169.05	0.57	0.57	0.01	0.14
LD*SES*Sequence	145.98	2	72.99	0.24	0.79	0.01	0.09
Grasping*LD*SES*Sequence	22.23	1	22.23	0.07	0.79	0.01	0.06
Error	29296.09	98	298.94				
Total	262248.00	121					

*Note:* Significant alpha level was determined *a priori* at an adjusted level of  $p \leq 0.02$  to account for analysis of both units of instruction

Results of the simple main effects test are shown in Table 30.

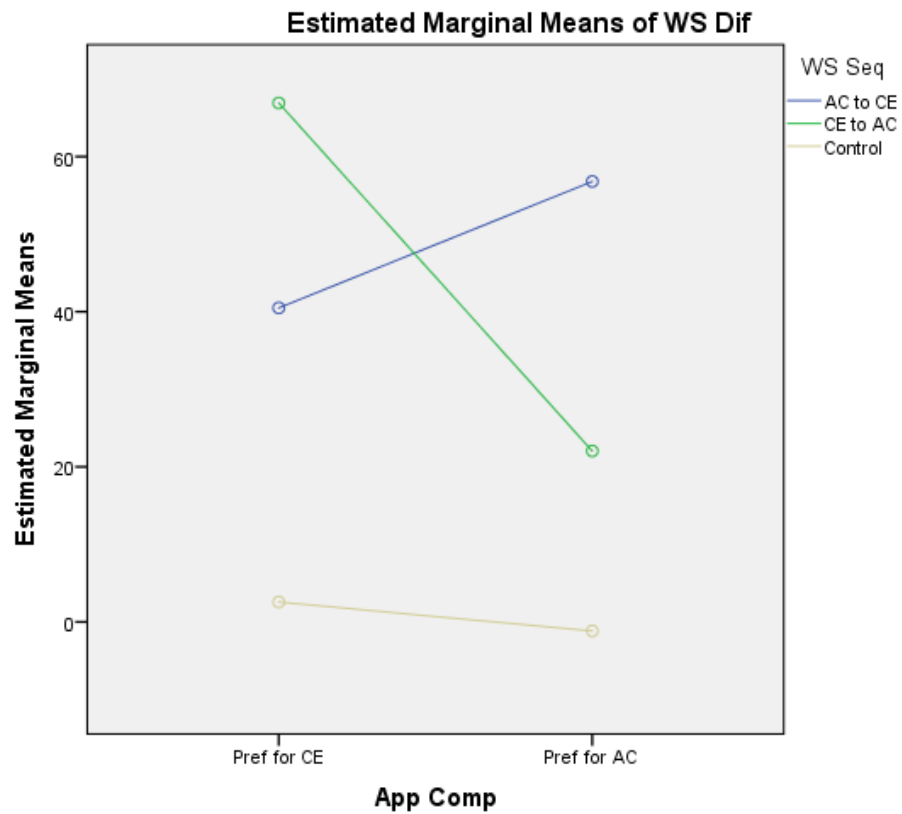
Table 30

*Simple Main Effects Tests of Cognitive Sequence and Preference for Grasping Experience on Water Science Unit Assessment*

Sequence	Preference for Grasping Experience			
	Apprehension (CE)		Comprehension (AC)	
	Difference	<i>p</i>	Difference	<i>p</i>
AC to CE	-16.31	0.01	16.31	0.01
CE to AC	44.86	0.001	-44.87	0.001
Control	3.73	0.68	-3.73	0.68

*Note.* Significance was determined based on an adjusted alpha level of  $p = 0.02$

The profile plot resulting from the interaction between preference for grasping information and sequence of the water science unit is presented in Figure 11.



*Figure 11.* Profile plot of interaction between preference for grasping information and sequence of water science instruction

### *Analysis of Interactions on Soil Science Assessments*

Following the completion of the analysis of means for the water science unit, the means were also compared through a univariate analysis for the soil science unit. The omnibus analysis revealed one significant main effect for sequence of instruction ( $F(2,98) = 31.02, p = 0.01, \eta_p^2 = 0.40$ ), and one significant interaction between preference for grasping experience and sequence of instruction ( $F(2,98) = 13.00, p = 0.00, \eta_p^2 = 0.21$ ). The interaction related to once again supporting the rejection of the null hypothesis in favor of the alternative hypothesis indicating interactions did exist between independent variables when the cognitive sequence of instruction was manipulated. The findings from the omnibus ANOVA for the soil science unit are shown in Table 31.

The significant interaction between cognitive sequence and learning style preference between apprehension and comprehension had a large effect size  $\eta_p^2 = 0.21$ , and as the main effect of cognitive sequence was included in the significant interaction, this main effect was not examined separately.

The interaction was further examined through a test of the simple main effects for change in soil science assessment score. Significant differences ( $p < 0.01$ ) were found based on the sequence of instruction. Students who preferred to grasp information through apprehension showed mean changes 27.15 points higher ( $p = 0.001$ ) than those who had a preference for grasping information through comprehension when the information in the unit was presented in a cognitive sequence beginning with a concrete experience. For students who preferred to grasp experience through comprehension,

difference scores were 19.77 points higher ( $p = 0.01$ ) when units of instruction were sequenced to begin with abstract conceptualization activities. Results of the simple main effects test are shown in Table 32.

Table 31

*ANOVA Table for the Effect of Learning Disability, Socioeconomic Status, Preference for Grasping Knowledge and Cognitive Sequence on Change in Pre and Posttest Scores on Soil Science Unit Assessments*

	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>p</i>	$\eta_p^2$	1- $\beta$
Grasping	53.20	1	53.20	0.22	0.64	0.01	0.07
LD	143.51	1	143.51	0.58	0.45	0.01	0.12
SES	309.96	1	309.96	1.25	0.27	0.01	0.20
Sequence	15824.89	2	7912.44	31.99	0.01*	0.40	1.00
Grasping*LD	26.84	1	26.84	0.11	0.74	0.01	0.06
Grasping*SES	372.74	1	372.74	1.51	0.22	0.02	0.23
Grasping*Sequence	6430.14	2	3215.07	13.00	0.00*	0.21	0.99
LD*SES	110.89	1	110.89	0.45	0.51	0.01	0.10
LD*Sequence	93.45	2	46.72	0.19	0.83	0.01	0.08
SES*Sequence	689.57	2	344.79	1.39	0.25	0.3	0.29
Grasping*LD*SES	256.28	1	258.28	1.04	0.31	0.01	0.17
Grasping*LD*Sequence	136.17	2	68.08	0.28	0.76	0.01	0.09
Grasping*SES*Sequence	62.03	2	31.01	0.13	0.88	0.01	0.07
LD*SES*Sequence	16.34	2	8.17	0.03	0.97	0.01	0.06
Grasping*LD*SES*Sequence	1.81	1	1.81	0.01	0.93	0.00	0.05
Error	24234.86	98	247.29				
Total	310351.00	121					

*Note:* Significant alpha level was determined *a priori* at an adjusted level of  $p \leq 0.02$  to account for analysis of both units of instruction

\* indicates significant results



Table 32

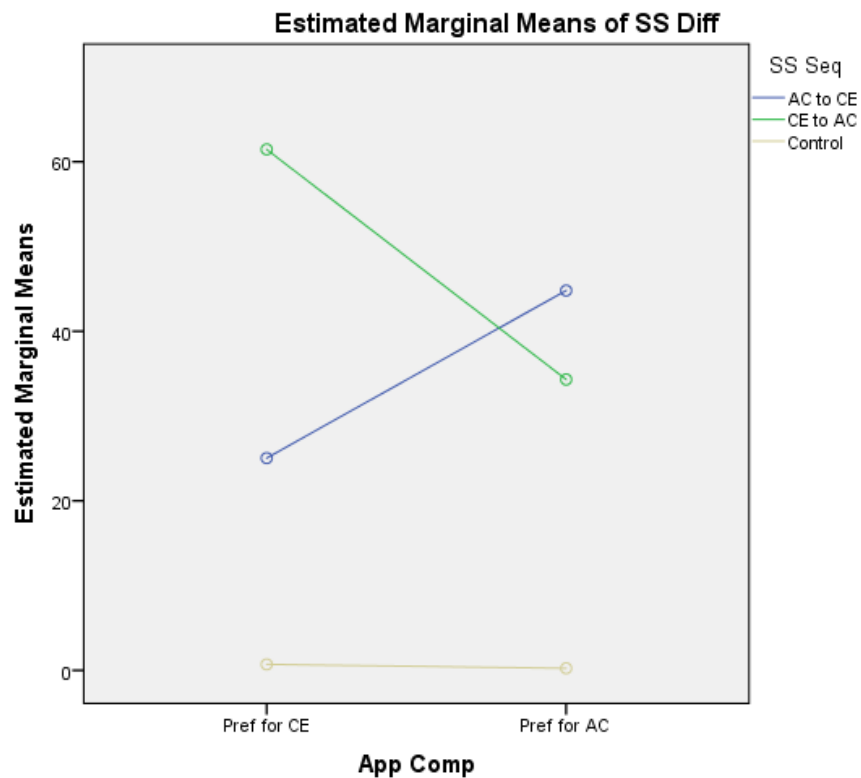
*Simple Main Effects Tests of Cognitive Sequence and Preference for Grasping Experience on Soil Science Unit Assessment*

Sequence	Preference for Grasping Experience			
	Apprehension (CE)		Comprehension (AC)	
	<i>Difference</i>	<i>p</i>	<i>Difference</i>	<i>p</i>
AC to CE	-19.77	0.01	19.77	0.01
CE to AC	27.15	0.001	-27.15	0.001
Control	0.46	0.96	-0.46	0.96

*Note.* Significance was determined based on an adjusted alpha level of  $p = 0.02$

\* indicates significant differences

The simple main effects of the interaction between cognitive sequence and preference for grasping information is illustrated well through the profile plot in Figure 12.



*Figure 12.* Profile plot of interaction between preference for grasping information and sequence of soil science instruction

The figure parallels the interaction observed in the water science unit, and depicts the differences in change pretest to posttest based on the cognitive sequence the soil science unit was presented in.

Based on the significant differences found in the means for both the water science and soil science units, the decision can be made with confidence to reject the null hypothesis associated with this research question and assert that significant interactions between the independent variables and the dependent variables existed. More specifically, the interaction between cognitive sequence of instruction for units of curriculum related to science in agricultural education accounted for a statistically and practically significant portion of the variance in means between groups.

### **Summary of Findings**

This section has included the statistical analyses of data as related to both the testing of statistical assumptions and the research question. The findings of this study include:

1. The statistical assumptions of MANOVA were violated, resulting in the need for examination through the use of two univariate ANOVAs, one for each of the units of instruction
2. Statistically and practically significant differences were found between groups for the water science unit
3. Statistically and practically significant differences were found between groups for the water science unit

4. For both units of instruction, there was a significant interaction between the preference for apprehension or comprehension and the cognitive sequence with which the information was presented
5. Preference for apprehension led to significantly greater change in score on units which were sequenced to begin with concrete experiences
6. Preference for comprehension led to significantly greater change in score on units which were sequenced to begin with abstract conceptualization activities
7. With significant interaction found, the null hypothesis was rejected in favor of the alternative hypothesis that interactions existed between learning disability, socioeconomic status, and learning style (preference for apprehension or comprehension) on STEM content assessments when the cognitive sequence of the content was manipulated.

These findings hold many points for discussion and recommendation for practice and research. The following chapter will provide additional discussion related to these findings.

## CHAPTER V

### SUMMARY, CONCLUSIONS, IMPLICATIONS, RECOMMENDATIONS AND DISCUSSION

It is no longer appropriate to teach students without addressing what we now know about the way the brain processes information (Sousa, 2010). A major issue facing modern agricultural education is *how* to teach complicated STEM concepts while catering to individual student learning needs (Myers & Dyer, 2004; Smith, et. al., 2014). Agricultural education has a foundation built on the premise of experiential learning theory (Roberts, 2006), which provides students with the opportunity to engage in a truly involved learning cycle built on concrete experience, reflective observation, abstract conceptualization, and active experimentation. The question is, how do the processes of ELT interact with student learning of STEM concepts in light of student differences on multiple factors?

The four previous chapters have discussed the examination of the topic of cognitive sequencing in STEM content assessments in agricultural education from a broad overview, review of relevant literature, methods for examining the topic, and findings of the experiment. This section will summarize the study, draw conclusions and implications from the findings and discuss recommendations for practice and further research related to this line of inquiry.

#### **Summary of Methods**

This study was conducted as a quasi-experimental cross-over examination of the factors related to student learning on STEM content assessments in agricultural

education which included three treatment groups and one control. The crossover design was chosen based on the ability of this design to examine the effects of two separate treatments on the participants, and decrease threats to external validity (Shadish, et. al., 2007). The dependent variables in this study were the change scores from pretest to posttest on two researcher-developed assessments for science-infused units of instruction. Independent variables of interest included student socioeconomic status, learning disability classification, and preference for grasping information through either apprehension (CE) or comprehension (AC) based on responses to the KLSI v. 3.1 instrument.

Students enrolled in the Principles of AFNR classes at four Texas high schools served as the population for this study ( $N = 128$ ). Through the treatments, a total of  $n = 121$  students completed the consent and assent process and were in attendance for at least 80% of the class time during the instructional units. Two separate week-long units of instruction were created, one in water science and one in soil science. Each of the two content area units were created with two cognitive sequences, one with lesson plans presenting each new concept through a concrete experience and moving to abstract conceptualization activities, and one lesson plan presenting each new concept first through abstract conceptualization and then progressing to a concrete experience activity. A group of experts in agricultural education, experiential learning theory, and curriculum planning assisted in the preparation and development of the treatment curricula.

The four sites were randomly assigned to one of four treatment groups, one site was designated as the control and participated in no instructional treatments. The remaining sites were assigned to receive the water science unit in one cognitive sequence and the soils science unit in the opposite cognitive sequence. This crossover of treatments allowed each student to receive instruction in both cognitive sequences. Both pretest and posttests were scored by the teachers for use in course grading and then scored again by the research team to verify scoring and ensure consistency in grading. The pretest and posttest scores for each student were compiled and used to determine a difference score for each unit.

To collect the information related to the independent variables, teachers provided the socioeconomic status of students as reported based on free and/or reduced lunch classification (Skiba, et. al., 2005), and the presence or absence of an IEP (Bender, 2008). In cases where information was not readily available to teachers, school district personnel provided the data. In addition, each student was administered the paper version of the *KLSI v. 3.1*, which provided an indicator of student learning style and preference for grasping information directly in line with the theoretical underpinnings of this study.

Resulting data were analyzed using IBM SPSS © version 23. The correlation between dependent variables was found insufficient to conduct a multivariate analysis of variance using the change scores as dependent variables, therefore, univariate analyses of variance were conducted for each dependent variable, adjusting the alpha level to prevent the possibility of committing a Type I error.

## **Summary of Findings**

There were seven findings which emerged through the statistical examination of data. These findings are all related to answering the research question: What interactions exist between the factors of cognitive sequence, learning style, socioeconomic status, and learning disability on student performance on STEM content assessments in agricultural education?

### *List of Findings*

The seven findings of this study are listed below:

1. The statistical assumptions of MANOVA were violated, resulting in the need for examination through the use of two univariate ANOVAs, one for each of the units of instruction.
2. Statistically and practically significant differences were found between groups for the water science unit.
3. Statistically and practically significant differences were found between groups for the water science unit.
4. For both units of instruction, there was a significant interaction between the preference for apprehension or comprehension and the cognitive sequence with which the information was presented.
5. Preference for apprehension led to significantly greater change in score on units which were sequenced to begin with concrete experiences.
6. Preference for comprehension led to significantly greater change in score on units which were sequenced to begin with abstract conceptualization activities.

7. With significant interaction found, the null hypothesis was rejected in favor of the alternative hypothesis that interactions existed between learning disability, socioeconomic status, and learning style (preference for apprehension or comprehension) on STEM content assessments when the cognitive sequence of the content was manipulated.

### **Finding One**

The first finding of this study was related to the testing of assumptions for use of statistical tools. The assumptions of a MANOVA include requirements for both the multivariate normal probability distribution and the equality of variance-covariance matrices (Meyers, et. al., 2013). Upon conducting the tests associated for these assumptions, it was found that Box's  $M$  was significant at the  $p = 0.001$  level, violating the assumption of multivariate normal distribution. In addition, Barlett's Test of Sphericity was performed to examine the equality of the variance-covariance matrices, yielding non-significant results ( $p = 0.52$ ). Based on these violations, the determination was made that the dependent variables were not conducive for analysis through a MANOVA. As a result, separate univariate analyses were performed for each of the units of instruction.

### **Finding Two**

The second finding of this study was statistically significant differences found between groups for the water science unit. The results of the omnibus ANOVA examination revealed significant differences ( $p \leq 0.02$ ) in the dependent variable. Significant differences were found for both preference for grasping experience ( $F(1,98)$



= 5.02,  $p = 0.02$ ,  $\eta_p^2 = 0.05$ ) and cognitive sequence of instruction ( $F(2,98) = 31.29$ ,  $p = 0.01$ ,  $\eta_p^2 = 0.39$ ). Along with a significant interaction ( $F(2,98) = 17.96$ ,  $p = 0.01$ ,  $\eta_p^2 = 0.27$ ) between the factors of cognitive sequence and preference for grasping experience. In addition to having statistical significance, both the main effects and the interaction effect had a large effect size ( $\eta_p^2 \geq 0.14$ ).

### **Finding Three**

Finding three was parallel to finding two but was related to the soil science unit. Statistically significant differences were found between groups for the soil science unit. This finding was determined by the omnibus ANOVA which resulted in a significant main effect for sequence of instruction ( $F(2,98) = 31.02$ ,  $p = 0.01$ ,  $\eta_p^2 = 0.40$ ), and a significant interaction between preference for grasping experience and sequence of instruction ( $F(2,98) = 13.00$ ,  $p = 0.00$ ,  $\eta_p^2 = 0.21$ ). Both of these differences were found to have a large effect size ( $\eta_p^2 \geq 0.14$ ) in relation to the population.

### **Finding Four**

The fourth finding was for both units of instruction, there was a significant interaction between the preference for apprehension or comprehension and the cognitive sequence with which the information was presented. Both units of instruction showed significant interaction between preference for grasping experience and cognitive sequence. Analysis of the differences yielded significant results at  $F(2,98) = 17.96$ ,  $p = 0.01$ ,  $\eta_p^2 = 0.27$  for the water science unit, and  $F(2,98) = 13.00$ ,  $p = 0.00$ ,  $\eta_p^2 = 0.21$  for the soil science unit.

### **Finding Five**

The fifth finding of this study was preference for apprehension led to significantly greater change in score on units which were sequenced to begin with concrete experiences. For both units of instruction, an examination of the simple main effects of the interaction between cognitive sequence and preference for apprehension, changes in scores were significantly higher when the unit was presented with each new concept presented beginning with a concrete experience. For the water science unit, preference for apprehension yielded a mean difference of 44.86 higher ( $p = 0.001$ ) change scores over students who had a preference for grasping information through comprehension. A similar effect was found in the examination of change on scores in the soil science unit, with students having a preference for apprehension showing a mean difference in change from pretest to posttest 27.15 higher ( $p = 0.001$ ) than students who had a preference for grasping information through comprehension.

### **Finding Six**

The sixth finding of this study was the inverse of finding five. Preference for comprehension led to significantly greater change in score on units which were sequenced to begin with abstract conceptualization activities. Like the preference for apprehension, students who had a preference for abstract conceptualization showed greater changes in their scores on both units when the cognitive sequence was designed to present each new concept with abstract conceptualization. For the water science unit, preference for comprehension resulted in a difference on mean change score of 16.31 ( $p = 0.01$ ) over those students who preferred grasping information through apprehension.

On the soil science unit, the mean of the change scores were 19.77 points higher ( $p = 0.01$ ) for students whose preference for grasping information was through comprehension.

### **Finding Seven**

The final finding of this study related to the decision on the null hypothesis. With significant interactions found for both units of instruction, the null hypothesis was rejected in favor of the alternative hypothesis that interactions existed between learning disability, socioeconomic status, and learning style (preference for apprehension or comprehension) on STEM content assessments when the cognitive sequence of the content was manipulated. Significant interactions were found within the means for the change scores on both units. While no significant interactions were found involving socioeconomic status or learning disability classification, the interaction between cognitive sequence and learning style was found to be both statistically and practically significant.

### **Conclusions**

Based on the findings, and taking into account the limitations and assumptions of the study design and resulting analysis, four conclusions can be drawn from this study. These conclusions will serve to guide the discussion and implications throughout the rest of this chapter.

1. No interactions were found between scores on STEM based content assessments and the factors of socioeconomic status and learning disability.

2. Students with a preference for grasping information via apprehension had greater change in scores on STEM based content assessments when the information was presented beginning with a concrete experience.
3. Students with a preference for grasping information via comprehension had greater change in scores on STEM-based content assessments when the information was presented beginning with abstract conceptualization.
4. Students performed with higher change scores in the unit cognitively sequenced to match their preference for learning, regardless of unit content.

### **Discussion and Implications**

Sousa (2011) said “teachers try to change the human brain every day, the more they know about how it learns, the more successful they can be” (p. 5). This study was designed as an exploratory examination of cognitive sequencing, in an effort to give agricultural educators background information for understanding how the cognitive principle of sequencing instruction might play a role in student understanding of STEM concepts. By basing this understanding of how students learn on experiential learning, which is already at the foundation of agricultural education (Baker, 2012; Roberts, 2006), we can begin to frame methods for instruction which might help teachers better guide students through the abstract STEM concepts they are being asked to teach (Myers & Dyer, 2004).

*Conclusion One: No interactions were found between scores on STEM based content assessments and the factors of socioeconomic status and learning disability*

It has long been established that both socioeconomic status (Hoover-Dempsey, Bassler, & Brissie, 1987; Sirin, 2005; White, 1982) and learning disability classification (Bender; 2004) are factors that play a role in student learning. The results of decades of research were not substantiated in this quasi-experimental study. There are several potential explanations for this conclusion.

First, many of the instructional assessments used to make claims as to the impact of SES and LD classification are based on standardized testing results (Bradley & Corwin, 2002; Bender, 2008). The criterion-referenced assessments in this study relied on assessment of students based on their performance related to the unit objectives. While questions were presented at different cognitive-levels, both the content and format of the assessments in this study differed from the standardized tests used in general education analyses.

The study design used for this quasi-experimental study included the use of crossover to account for individual differences in learning. In addition, comparisons were only made based on the changes in scores, rather than the pre and post test scores individually. The use of crossover and change scores in analysis may mask differences in groups which would be found if a repeated measures design were used (Tabachnick & Fidel, 2007).

Another possible explanation is that while these groups differed from the rest of the population of their schools, there were not large enough differences in either the SES

classification or the LD classification between these sites as a whole and the national population to realize significant findings. Although students classified as low SES were found at each of the sites, none of the sites were in communities which would be considered economically depressed. Differences based on SES classification may be found between groups if sites were selected in areas where the baseline poverty level were substantially lower than the sites in this study.

Because all of the students in this study were in general education courses, it is likely that the students with learning disabilities in this study required only minor modifications to instruction. It is a limitation to this study that individuals with learning disabilities could not be identified based on their specific accommodation plans.

*Conclusion Two: Students with a preference for grasping information via apprehension had greater change in scores on STEM based content assessments when the information was presented beginning with a concrete experience*

Kolb (2015) stated “the complex structure of learning allows for the emergence of individual, unique possibility-processing structures or styles of learning. Through their choices of experience, people program themselves to grasp reality through varying degrees of emphasis on apprehension or comprehension” (p. 100). With this statement, Kolb highlights the importance of examining preferences for grasping information.

Sequencing instruction has long been a topic of interest with regard to educational theorists (Andersson, et. al., 2001; Bloom, 1956, James, 1890; Reigeluth, 2013; Webb, 1997). James (1890) highlighted the importance of beginning with a concrete experience and stressed that a concept could not become known until first it had

been both experienced and then acted upon. Interestingly enough, in an expansive search of ELT literature, a definitive statement regarding the beginning point for the learning cycle could not be found. Kolb (1984, 2015) alludes that the learning cycle may be entered at any point, but must be sequential from the point of entry in the earliest stages of development. Dewey (1916) firmly stated his belief that all knowledge should begin with an experience, and outlined experience as the first point in knowing.

This study allows the conclusion to be made that for both the water science and soil science units of instruction, greater changes in scores were found for students who preferred to grasp experience through apprehension when the units were sequenced to begin with a concrete experience. The statistical and practical significance of this finding warrant future investigation as to how this preference for cognitive sequence in a unit might play a role in agricultural education and the integration of STEM concepts.

An important note related to this conclusion is the careful attention to designing units which were congruent in aspects outside of cognitive sequencing. Using Gagne's (1965) nine events of instruction in design helped to ensure that the lessons were congruent with the exception of cognitive sequence, not units comparing a high quality outline for instruction with a poor one. The experimental curricula were developed to meet the established needs of students, outlining information in a systematic fashion.

Many of the concepts in STEM education are abstract in nature (Maltese, et. al., 2014), and the hands-on nature of agricultural education and other CTE courses have been seen as a platform for delivering these concepts (Stone, 2010). For students who prefer to grasp information through apprehension, the presentation of abstract concepts

through abstract conceptualization may not provide the stimulus they need to transform the information. Zull (2002) states “we are more likely to trust sensory input from the experience itself” (p. 145). This is especially true for students who prefer to grasp information through apprehension (Kolb, 2015).

Providing students preferring apprehension over comprehension a concrete experience at the beginning of the instruction allows them to have an experience with which to tie the abstractions to (Garlick, 2010; Kolb, 2015). According to Kolb (2015) those who prefer concrete experience (apprehension) have “a concern with the uniqueness and complexity of present reality as opposed to theories and generalizations” (p. 105). It is important to note that within the confines of ELT, the entire learning cycle must be completed in order for learning to occur. Students who have a preference for apprehension are not likely to learn only through the concrete experience, it must be supplemented by reflective observation, abstract conceptualization, and active experimentation in order for the intent of ELT to be met (Baker, 2012; Kolb, 2015).

The implications of this finding are especially important for agricultural education. Most of the current educational curriculum is designed in a sequence which begins with abstract concepts and then moves to concrete applications (Reigeluth, 2013). For students who prefer to grasp experience through apprehension, there is the possibility that the most commonly used educational sequence could be doing them a great disservice. This study revealed that a majority of students  $n = 86$  had a preference for grasping experience through apprehension. If the proportion of students who prefer apprehension over comprehension is similar in the total population of agricultural



education students, it could mean that there are a large number of students who would benefit from a modification to sequenced instruction beginning with concrete experiences.

The concept of beginning with the sequence has ties to the foundational scholars of ELT. James (1890) believed that without the concrete experience, there was no way to completely translate information into knowledge. Dewey stated his strong convictions that the experience should guide the education. For students who preferred to grasp information through apprehension in this study, that certainly seemed to be the case. Both Sousa (2011) and Zull (2002) highlighted the importance of having a context to tie abstractions to in the brain before learning could occur. This study highlighted that importance for students who prefer to learn through more hands-on or applied experiences.

Researchers in agricultural education have suggested that agriculture classes can be more effective at increasing student science scores than standalone science classes (Clark, et. al., 2013; Myers & Dyer, 2004; Ricketts, Duncan, & Peake, 2006), pointing to the applied nature of agriculture classes and their ability to provide concrete application of abstract principles. It may be only one step further to sequence instruction so that concrete experience happens at the beginning of the learning cycle, allowing those students with a preference for grasping experience through apprehension a basis for tying abstract concepts to (Sousa, 2011).

*Conclusion Three: Students with a preference for grasping information via comprehension had greater change in scores on STEM-based content assessments when the information was presented beginning with abstract conceptualization*

A preference for abstract conceptualization is marked by “thinking as opposed to feeling” (Kolb, 2015, p. 105). For students who had a preference for grasping information through comprehension rather than apprehension, scores were higher on the units of instruction sequenced to begin with abstract conceptualization. Kolb (2015) described the process of knowing by comprehension on equal footing with knowing by apprehension, although some of the foundational scholars of ELT show a decided preference for grasping through apprehension (Dewey, 1916; James, 1890).

In the realm of ELT, Kolb (2015) discussed the differences in the grasping of experience:

Appreciative apprehension and critical comprehension are thus fundamentally different processes of knowing. Appreciation of immediate experience is an act of attention, valuing, and affirmation, whereas critical comprehension of symbols is based on objectivity, dispassionate analysis, and skepticism (p. 158)

This examination of the differences in the two dimensions of prehension illustrates the differences that may be seen in students who have a preference for comprehension over those with a preference for apprehension.

STEM education fields often require a focus on abstract concepts (Maltese, et. al., 2014; Stone, 2011). Students who are more analytical in nature and more prone to abstract conceptualization are perhaps more likely to excel in STEM fields. In regard to

the KLSI instrument, Kolb (2015) posits more engineers and scientists demonstrating a preference for grasping experience through comprehension.

Students with a preference for grasping experience through comprehension were found to have higher mean changes in scores when new concepts were presented through abstract conceptualization first. From a neuroscience standpoint, this would relate to Zull's (2002) assertion that an abstract concept must first be evaluated by the mind in relation to other abstract concepts before the mind can process experiences based on the abstraction.

What implications does this have for agricultural education? First, the traditional model of curriculum design, which includes instruction in abstract concepts followed by concrete application of those abstractions is well-suited for students who prefer to grasp experience through comprehension. These students likely excel in agricultural education classes and are able to easily move through the learning cycle when STEM concepts are presented in traditional instructional formats in agricultural education classes. Educators should continue to be mindful that these students still need to realize the other three modes of learning for the completion of learning through ELT.

*Conclusion Four: Students performed with higher change scores in the unit cognitively sequenced to match their preference for learning, regardless of unit content*

The results of this study highlighted the importance of cognitive sequencing on change in score from pretest to posttest. By using a crossover design, each student could be evaluated in relation to their preference for grasping experience and their performance on purposively sequenced units. For the  $n = 121$  students involved in this

study, differences were evident. The results reveal that sequencing of instruction resulted in greater changes in assessment scores as an interaction with preference for grasping experience. Student differences based on cognitive sequence have direct implications for agricultural educators as they work to instruct STEM concepts.

Students with both types of preferences exist in an agricultural education classroom, so which of the cognitive sequences is better suited for development of curriculum materials? Perhaps rather than looking at the sequence as an either or concept, the answer would be to include both sequences within units in order to ensure the needs of all students are met. Kolb (2015) stated:

The relationship between apprehension and comprehension is dialectic in the Hegelian sense that although the results of either process cannot be entirely explained in terms of the other, these opposite processes merge toward a higher truth that encompasses and transcends them (p. 162).

By focusing on the holistic process of ELT, it can be determined when and how cognitive sequencing is most appropriate in the development of STEM-based units of instruction.

The findings of this study and subsequent conclusions are reminiscent of Kolb's (2015) musings on learning preferences. He stated "through their choices of experience, people program themselves to grasp reality through varying degrees of emphasis on apprehension or comprehension" (p. 100). This was certainly the case in this study, with a small extension. Those who preferred to grasp through apprehension performed better when they had a concrete experience as their entry to the learning cycle, while those

with a preference for grasping information through comprehension performed better when they could first grasp the concept through abstract conceptualization.

Sequencing instruction based on individual student preferences for grasping information has close ties to the literature related to differentiated instruction.

Tomlinson (2001) points out the importance of tailoring educational practices to meet the needs of each student. The findings of this study give an example of just how critical differentiated instruction is when dealing with STEM concepts in agricultural education classes. Students in this study demonstrated a preference for grasping information and showed drastically higher scores when they were given the opportunity to grasp information in a sequence tailored to their preference. This small change to educational methods may have broad-reaching effects, not only for STEM concepts in agricultural education, but for education as a whole.

It is important to note the structure of the experimental curricula used in this study. Using Gagne's (1965) nine events of instruction allowed the units to be presented systematically, using known cognitive practices such as recall of prior information, readiness to learn, and stated objectives (Sousa, 2011). These factors alone have been shown to increase student learning (Driscoll, 2004). Combining those factors with a sequence beginning with student's preferred method for grasping information may prove to be an important change to the way educational curriculum is developed and the way teachers are presenting information.

This conclusion serves as a starting point for a discussion on how our practices can best meet the needs of our students. Agricultural education is charged with

providing context to abstract STEM concepts (Myers & Dyer, 2004). To this point, there has been little research on the best ways to deliver this content effectively (Stone, 2010). Perhaps by returning to our ELT roots (Roberts, 2006; Baker, et. al. 2012) and differentiating our instruction based on individual learning preferences (Tomlinson, 2001) through cognitive sequencing, we can stimulate the change our field needs to meet the challenge.

Students being taught the same content in this study, and assessed using the same assessments responded differently based on their learning preferences. Sequencing the instruction in a manner geared toward learning preferences made a difference in student performance. The conclusions of this study highlight clearly that it is not only what agricultural educators are teaching in regards to STEM concepts in agricultural education, it is how they are teaching it that may make the critical difference for our students.

### **Recommendations for Practice**

Based on the findings and conclusions of this study, there are several recommendations for practice which can be made for secondary agricultural educators:

1. This study allowed us to conclude that students showed greater change in scores on STEM content assessments in agricultural education when the units were sequenced to match their preference for grasping experience, but as both preferences exist in a secondary agricultural education classroom, it is recommended to alternate and combine instruction in STEM concepts from both apprehension and comprehension of the prehension dialectic.

2. A focus on cognitive sequencing within the framework of ELT should be emphasized. The importance of understanding how repeated sequences could impact students with differing preferences for grasping information should be noted. For example, if multiple units of instruction are sequences beginning with abstract conceptualization activities, teachers should consider revising lesson plans to include lessons sequenced beginning with a concrete experience to allow students with a preference for grasping experience through apprehension the opportunity to learn in the sequence best suited to their learning style.
3. Careful attention should be paid during the design of instruction in agricultural education to ensure that students are receiving exposure to the complete learning cycle as defined through ELT. This has wide reaching implications for the field. In addition, vendors of curriculum materials should use the learning cycle as a model with which to build lessons and develop curricula.
4. Students should be assessed through the *KLSI* or similar instrument to determine their preference for grasping experience. Results of these assessments should be used to guide instructional procedures toward the specific needs of classes and/or students. The results of this study indicate the importance of knowing how students prefer to grasp information. Using these assessments could provide substantial assistance for both primary instruction and remediation for students who are struggling in grasping STEM concepts in agricultural education classes. Additional recommendations for practice can be made for teacher educators in

agricultural education:

1. Teacher educators should ensure teaching methods courses for preservice teachers include a substantial explanation of experiential learning theory and the learning cycle. This explanation should include not only lecture-based instruction on the components of ELT, but also provide instruction that models what each of the learning modes of ELT looks like in a secondary classroom. This will better prepare teachers to utilize ELT as a framework for instruction.
2. Teacher educators should prepare preservice educators to recognize the four components of the learning cycle and develop preservice instruction which includes how to incorporate these modes into lesson development. Preservice educators should be assessed on their ability to integrate these components into a lesson plan, unit plan, and assessments.
3. Pre-service teachers should be made aware of the potential effects of cognitive sequencing on student learning. They should be given the opportunity to develop lessons which are not sequenced in a traditional AC to CE format. If preservice teachers are preparing to meet the needs of all their students, they should be prepared for students who prefer to grasp information beginning with a concrete experience. In this study, more students preferred grasping via apprehension over comprehension. Allowing preservice teachers the opportunity to familiarize themselves with how to present information which will best reach the majority of their students is critical in their preparation.
4. In addition to helping preservice teachers develop their own cognitively sequenced units, they should also be instructed on methods for modifying the



cognitive sequence of existing curriculum materials. Most available curricula are presented in an order which begins with abstract conceptualization (Reigeluth, 2013). In order to be effective, preservice teachers should learn the best method for taking existing curriculum materials and modifying the sequence, so that concrete experiences could be presented first.

5. Professional development should be created and presented to in-service teachers to highlight the effects of cognitive sequencing based on learning style. In-service should include instruction on how to present new concepts using both a apprehension and comprehension beginning point. This will ensure that teachers are prepared to meet the individual needs of their students. Combining the knowledge of how to cognitively sequence instruction with an assessment of students in agricultural education courses could give teachers a prescriptive method for increasing student learning of STEM content.

### **Recommendations for Future Research**

The results of this study lead to additional areas for research related to the concepts of cognitive sequencing, STEM education, and experiential learning theory in agricultural education:

1. An experiment should be conducted to determine the effects of this study if replicated in a clinical setting to see if interactions persist in a controlled environment.

2. This study should be replicated through a quasi-experiment in other areas of STEM content to determine if cognitive sequencing plays a role in student learning.
3. The differences in student learning should be examined using cognitive sequencing of the transformation dimension of ELT to determine if differences exist when transformation of knowledge begins through intention or extension.
4. A replication of this quasi-experiment should be conducted using alternating cognitive sequences within a unit, to determine what effects the alternating sequence has for students with differing preferences for grasping experience.
5. The units of instruction for this study were both based on common scientific principles. Differences in student learning and interactions between factors should be examined through a replication of the quasi-experiment using units with more basic scientific principles.
6. The study should be replicated using the *KLSI v. 4*, which includes a measurement of flexibility in learning preference.
7. The role of teacher preference for comprehension or apprehension should be examined in relationship to student learning and cognitive sequencing.

### **Concluding Remarks**

Cognitive sequencing is a concept that has many implications for learning. Theories related to sequencing from notable educational psychologists like William James, Vygotsky, Piaget, and Dewey are being substantiated through findings in modern neuroscience (Willis, 2010). At the crossroads between neuroscience and

educational theory lies the classroom teacher (Sousa, 2011), who is working through theory to change the brain for students every day.

Experiential learning theory is a valuable tool for agricultural education, one that many believe is at the very core of our profession. Attention to this theory as a systematic method for instruction, rather than a suggested principle could yield the understanding of how to integrate content and STEM concepts more effectively for all students.

This study was conducted with a primary goal. The main goal of this research was not to build upon theory or substantiate the research of academics, though it would certainly be wonderful if these implications existed. The main goal of this research was to help those who spend every day working in the classroom. The importance of cognitive sequencing in relation to STEM concepts and experiential learning theory has been highlighted by this examination, using real teachers and real students, and has been found to have applied effects on student learning outcomes. This concept has the potential to help agricultural educators and students, and that is where the true impact lies.

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APPENDIX A

EXAMPLE EXPERIMENTAL LESSON PLANS

## LESSON PLAN SEQUENCED FROM AC TO CE

### **Course: Principles of AFNR**

#### **Unit: Science in Agriculture: Water Science**

#### **Unit Objectives: Students Will Be Able To...**

1. Understand the importance of water in agriculture
  - a. Describe the Water Cycle
  - b. Explain the importance of water for agriculture
  - c. Examine the affects of drought on agricultural industries
2. Examine the chemistry of water
  - a. Describe the chemical structure of water
  - b. Understand the principle of polarity as it relates to water molecules
3. Explore the chemical interactions of water
  - a. Explain the chemical processes involved with adhesion, cohesion, and surface tension
  - b. Demonstrate understanding of adhesion, cohesion, and surface tension
4. Analyze the importance of maintaining clean water
  - a. Understand the importance of maintaining clean water
  - b. Explain the chemistry behind water contamination
  - c. Differentiate between point and non-point pollution
  - d. Analyze methods for agriculturalists to reduce water pollution

#### **Daily Objectives**

3. Explore the chemical interactions of water
  - a. Explain the chemical processes involved with adhesion, cohesion, and surface tension
  - b. Demonstrate understanding of adhesion, cohesion, and surface tension

#### Materials Needed (Equipment):

- Water Science Day 3 Presentation (WSP3A)
- Water Science Note Packet (WSNP1A) (1 per student)\
- Water droppers (1 per student)
- Pennies (1 per student)
- Water
- Paper clips (1 per student)
- Small paper cup (1 per student)

#### Facilities:

- Classroom
- Projector

Interest Approach:

PPT Slide 2

“Have you ever experienced this? (picture of condensed tea glass)

- Why does it happen?
- In groups, discuss this phenomenon and try to come up with a reason for the condensation
- Today, we are going to talk about why this happens, and how these principles can be applied to other situations”

Have students relate the information that they gather from their groups.

Hold a class discussion where you explain that the polar characteristics of water that were discussed the prior day lead to condensation on the glass. The electrons from the water molecules in the air are slowed down by the cool temperature of the glass, and that allows them to hold onto the glass, then pull other water molecules from the air.

Objective 3a: Explain the chemical processes involved with adhesion, cohesion, and surface tension

<b>Curriculum (Content) (What to teach)</b>	<b>Instruction (Methodology) (How to teach)</b>
Adhesion <ul style="list-style-type: none"><li>• Water is a polar molecule</li><li>• It is continually looking for other polar molecules to bond to</li><li>• Adhesion is the process of hydrogen bonds forming between water molecules and other molecules</li></ul>	Slide 6: Have students recall the concept of polarity that was discussed in the previous lesson. Tell them that everything we discuss today will be based on the concept of polarity.  Have them capture the information about adhesion and relate that the picture is showing the adhesion of water to a spiderweb
Chemistry of Adhesion <ul style="list-style-type: none"><li>• Adhesion is the bonding of water molecules when they come in contact with another molecule.</li><li>• The hydrogen bonds formed in adhesion are typically not as strong as the bonds formed in cohesion.</li></ul>	Slide 7: Show students the graphic and explain the bonding that occurs between the hydrogen molecules and slightly negative atoms. Explain the importance of adhesion to a soil particle. This process holds the water in the soil so that it is available for plants to take in through the roots. Tell students that Adhesion is the process of water Adding other molecules to it

<p>Cohesion</p> <ul style="list-style-type: none"> <li>• Water sticks to itself too</li> <li>• Cohesion is water molecules forming hydrogen bonds with other water molecules</li> <li>• Cohesion is the reason water beads up</li> </ul> <p>Chemistry of Cohesion</p> <ul style="list-style-type: none"> <li>• Cohesion is simply the water molecule</li> <li>• polarity creating hydrogen bonds</li> <li>• between water molecules</li> </ul> <p>Chemistry of Cohesion</p> <ul style="list-style-type: none"> <li>• Cohesion is important in the formation of ice.</li> <li>• Liquid water has cohesive hydrogen bonds that constantly break and reassemble</li> <li>• In ice, the hydrogen bonds become stable and do not reassemble</li> </ul> <p>Surface Tension</p> <ul style="list-style-type: none"> <li>• Surface tension is the strength of a surface of water because of the cohesion of water molecules</li> <li>• Can you think of some reasons that surface tension is important?</li> </ul> <p>Chemistry of Surface Tension</p> <ul style="list-style-type: none"> <li>• same principle as cohesion</li> </ul> <p>-except-</p> <ul style="list-style-type: none"> <li>• Water molecules at the surface of the water have</li> </ul>	<p>Slide 8: talk to students and tell them that COhesion is water COoperating with other water molecules</p> <p>Slide 9: show students the graphic and explain that the water molecules are holding together tightly</p> <p>Slide 10: talk about ice and the difference between stable and unstable hydrogen bonds. Explain that this is the reason that water expands when it freezes, because the stable hydrogen bonds force the water molecules to stay farther apart than the unstable hydrogen molecules in liquid water</p> <p>Slide 11: Ask them if they have ever seen a spider on water like this? Tell them the importance of surface tension because it provides a means for water holding together at the top.</p> <p>Ask them the reasons that surface tension is important and guide students to answers like boats floating, being able to have things rest on the surface of the water, etc.</p> <p>Slide 12: have students look at the graphic and explain that the reason the surface bonds are stronger is that there are less water molecules around the molecules on the surface to have bonding sites</p>
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fewer Chances to bond <ul style="list-style-type: none"> <li>• Bonds formed on the surface are slightly stronger than the hydrogen bonds formed in cohesion</li> </ul>	
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Objective 3: Demonstrate understanding of adhesion, cohesion, and surface tension

Have students complete the adhesion, cohesion and surface tension activity (WSW2A)

<b>Curriculum (Content) (What to teach)</b>	<b>Instruction (Methodology) (How to teach)</b>
Adhesion <ul style="list-style-type: none"> <li>• Worksheet section 1</li> </ul> Cohesion <ul style="list-style-type: none"> <li>• Worksheet section 2</li> </ul> Surface Tension <ul style="list-style-type: none"> <li>• Worksheet section 3</li> </ul>	Adhesion lab: Students will take the piece of paper towel and hold it into the water to make sure that it is pulling up water. They will then need to make sure to answer the worksheet questions to explain why this is adhesion and why this is also cohesion  Cohesion lab: students will test the theory of cohesion by seeing how many drops of water they can get onto the top of the penny. They will then need to explain their understanding of the concept of cohesion on the worksheet  Surface tension lab: Students will try to see if they can balance a paper clip on the surface of the water. They will need to answer the worksheet questions to demonstrate their knowledge of the principles behind the concepts

Evaluation:

References:

**Course: Principles of AFNR**

**Unit:** Science in Agriculture: Water Science

**Unit Objectives: Students Will Be Able To...**

5. Understand the importance of water in agriculture
  - a. Describe the Water Cycle
  - b. Explain the importance of water for agriculture
  - c. Examine the affects of drought on agricultural industries
6. Examine the chemistry of water
  - a. Describe the chemical structure of water
  - b. Understand the principle of polarity as it relates to water molecules
7. Explore the chemical interactions of water
  - a. Explain the chemical processes involved with adhesion, cohesion, and surface tension
  - b. Demonstrate understanding of adhesion, cohesion, and surface tension
8. Analyze the importance of maintaining clean water
  - e. Understand the importance of maintaining clean water
  - f. Explain the chemistry behind water contamination
  - g. Differentiate between point and non-point pollution
  - h. Analyze methods for agriculturalists to reduce water pollution

**Daily Objectives**

4. Explore the chemical interactions of water
  - a. Demonstrate understanding of adhesion, cohesion, and surface tension
  - b. Explain the chemical processes involved with adhesion, cohesion, and surface tension

Materials Needed (Equipment):

- Water Science Day 3 Presentation (WSP3A)
- Water Science Note Packet (WSNP1A) (1 per student)\
- Water droppers (1 per student)
- Pennies (1 per student)
- Water
- Paper clips (1 per student)
- Small paper cup (1 per student)

Facilities:

- Classroom



- Projector

Interest Approach:

PPT Slide 2

“Have you ever experienced this? (picture of condensed tea glass)

- Why does it happen?
- In groups, discuss this phenomenon and try to come up with a reason for the condensation
- Today, we are going to talk about why this happens, and how these principles can be applied to other situations”

Have students relate the information that they gather from their groups.

Hold a class discussion where you explain that the polar characteristics of water that were discussed the prior day lead to condensation on the glass. The electrons from the water molecules in the air are slowed down by the cool temperature of the glass, and that allows them to hold onto the glass, then pull other water molecules from the air.

**Objective 3a:** Demonstrate understanding of adhesion, cohesion, and surface tension

Slide 5-6: Have students complete the adhesion, cohesion and surface tension activity (WSW2B)

<b>Curriculum (Content) (What to teach)</b>	<b>Instruction (Methodology) (How to teach)</b>
Adhesion <ul style="list-style-type: none"> <li>• Worksheet section 1</li> </ul>	Adhesion lab: Students will take the piece of paper towel and hold it into the water to make sure that it is pulling up water. They will then need to make sure to answer the worksheet questions to explain why this is adhesion and why this is also cohesion
Cohesion <ul style="list-style-type: none"> <li>• Worksheet section 2</li> </ul>	Cohesion lab: students will test the theory of cohesion by seeing how many drops of water they can get onto the top of the penny. They will then need to explain their understanding of the concept of cohesion on the worksheet
Surface Tension <ul style="list-style-type: none"> <li>• Worksheet section 3</li> </ul>	

	<p>Surface tension lab: Students will try to see if they can balance a paper clip on the surface of the water. They will need to answer the worksheet questions to demonstrate their knowledge of the principles behind the concepts</p> <p>HAVE THEM HOLD ONTO THEIR WORKSHEETS AND COME BACK TO THEM AFTER THE NOTES SECTION</p>
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**Objective 3b:** Explain the chemical processes involved with adhesion, cohesion, and surface tension

<b>Curriculum (Content) (What to teach)</b>	<b>Instruction (Methodology) (How to teach)</b>
<p>Adhesion</p> <ul style="list-style-type: none"> <li>• Water is a polar molecule</li> <li>• It is continually looking for other polar molecules to bond to</li> <li>• Adhesion is the process of hydrogen bonds forming between water molecules and other molecules</li> </ul> <p>Chemistry of Adhesion</p> <ul style="list-style-type: none"> <li>• Adhesion is the bonding of water molecules when they come in contact with another molecule.</li> <li>• The hydrogen bonds formed in adhesion are typically not as strong as the bonds formed in cohesion.</li> </ul>	<p>Slide 8: Have students recall the concept of polarity that was discussed in the previous lesson. Tell them that everything we discuss today will be based on the concept of polarity.</p> <p>Have them capture the information about adhesion and relate that the picture is showing the adhesion of water to a spiderweb</p> <p>Slide 9: Show students the graphic and explain the bonding that occurs between the hydrogen molecules and slightly negative atoms. Explain the importance of adhesion to a soil particle. This process holds the water in the soil so that it is available for plants to take in through the roots. Tell students that Adhesion is the process of water ADDing other molecules to it</p> <p>Explain that in the paper towel</p>

	activity, the water was adhering to the paper towel
<p>Cohesion</p> <ul style="list-style-type: none"> <li>• Water sticks to itself too</li> <li>• Cohesion is water molecules forming hydrogen bonds with other water molecules</li> <li>• Cohesion is the reason water beads up</li> </ul>	<p>Slide 10: talk to students and tell them that COhesion is water COoperating with other water molecules</p>
<p>Chemistry of Cohesion</p> <ul style="list-style-type: none"> <li>• Cohesion is simply the water molecule</li> <li>• polarity creating hydrogen bonds</li> <li>• between water molecules</li> </ul>	<p>Slide 11: show students the graphic and explain that the water molecules are holding together tightly</p> <p>Talk about the penny experiment and the chemical properties of cohesion which allowed the water to build up on the penny</p>
<p>Chemistry of Cohesion</p> <ul style="list-style-type: none"> <li>• Cohesion is important in the formation of ice.</li> <li>• Liquid water has cohesive hydrogen bonds that constantly break and reassemble</li> <li>• In ice, the hydrogen bonds become stable and do not reassemble</li> </ul>	<p>Slide 12: talk about ice and the difference between stable and unstable hydrogen bonds. Explain that this is the reason that water expands when it freezes, because the stable hydrogen bonds force the water molecules to stay farther apart than the unstable hydrogen molecules in liquid water</p>
<p>Surface Tension</p> <ul style="list-style-type: none"> <li>• Surface tension is the strength of a surface of water because of the cohesion of water molecules</li> <li>• Can you think of some reasons that surface tension is important?</li> </ul>	<p>Slide 13: Ask them if they have ever seen a spider on water like this? Tell them the importance of surface tension because it provides a means for water holding together at the top.</p> <p>Ask them the reasons that surface tension is important and guide students to answers like boats floating, being able to have things rest on the surface of the water, etc.</p>

<p>Chemistry of Surface Tension</p> <ul style="list-style-type: none"> <li>• same principle as cohesion</li> </ul> <p>-except-</p> <ul style="list-style-type: none"> <li>• Water molecules at the surface of the water have fewer Chances to bond             <ul style="list-style-type: none"> <li>• Bonds formed on the surface are slightly stronger than the hydrogen bonds formed in cohesion</li> </ul> </li> </ul>	<p>Slide 14: have students look at the graphic and explain that the reason the surface bonds are stronger is that there are less water molecules around the molecules on the surface to have bonding sites</p> <p>Relate the concept of surface tension to the paper clip activity they have already completed</p> <p>Slide 15: Give students the chance to finish the other questions on their worksheet using the information they have gathered in their notes</p>
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Evaluation:

References:

APPENDIX B

EXAMPLE COMMON UNIT ASSESSMENT

Name: \_\_\_\_\_

Date: \_\_\_\_\_

Period: \_\_\_\_\_

## **Science of Water PostTest (WSAX)**

Section 1- Matching: Please match the definition on the left to the words on the right. Words may be used more than once or not at all. (3 pts each)

- \_\_\_\_ 1. Water sticking to itself
  - \_\_\_\_ 2. The reason that things can float on top of water
  - \_\_\_\_ 3. Water sticking to something else
  - \_\_\_\_ 4. The bonds formed between hydrogen and oxygen in a water molecule
  - \_\_\_\_ 5. The weaker bonds formed between water molecules
  - \_\_\_\_ 6. When cohesion in water molecules inside a plant causes water to be pulled up from the roots of the plant
- A. Adhesion
  - B. Capillary Action
  - C. Cohesion
  - D. Hydrogen Bonds
  - E. Polar Covalent Bonds
  - F. Surface Tension

Section 2- Basics of Atoms: Name the three components of atoms, give their charge, and where they are found in the atom: (2 pts. per blank)

Component	Charge	Where Found (nucleus or outer ring)
7.		
8.		
9.		

Section 3- Fill in the Blank: please complete the sentence using information you gained through this unit 2 pts. per blank)

10. Water is considered polar because the \_\_\_\_\_ are not evenly shared between the oxygen and hydrogen atoms. This makes the hydrogen end of the molecule have a slightly \_\_\_\_\_ charge and the oxygen end of the molecule have a slightly \_\_\_\_\_ charge.

11. The process of \_\_\_\_\_ is cohesion between water molecules inside plants. This process allows vegetative plants to remain upright instead of \_\_\_\_\_.

12. If a plant has lost enough water that it will not recover no matter how much water you give it, it has reached the \_\_\_\_\_.

Section 4- Short Answer: Please give a brief answer for each of the questions.

13. Please define the term “universal solvent”. How does water work as a solvent? (4 pts)

14. Share the differences between adhesion and cohesion. Give one example of how adhesion is important in agriculture and one example of how cohesion is important in agriculture. (4 pts)

15. Why is surface tension important in agriculture? (4 pts)

16. Please list three reasons that water is important to agriculture. (6 pts.)

17. How do you think the chemistry of water help it being an important molecule for life on Earth? Explain your answer in at least three complete sentences. (10 pts.)

18. What do you feel is the most important property of water molecules as they relate to agriculture? Please detail this property and how it works, and explain why you think this property is the most important. (10 pts.)

Section 5- Drawing:

19. Draw a water molecule. Make sure to label oxygen, hydrogen, and polar covalent bonds.  
(20 pts.)



## APPENDIX C

### COMMON ASSESSMENT CODING BY OBJECTIVE AND COGNITIVE LEVEL

## **Assessment Overview WSAX**

### Unit Objectives

- A. Describe the chemical structure of water
- B. Draw and label a water molecule
- C. Understand the principle of polarity as it relates to water molecules
- D. Explain the chemical processes involved with adhesion, cohesion, and surface tension
- E. Relate the chemical processes of water to their importance for agriculture

### Test Questions by Objective

Objective	Addressed by Test Questions	Total Points
A. Describe the chemical structure of water	4, 7, 8, 9, 17	22
B. Draw and label a water molecule	19	20
C. Understand the principle of polarity as it relates to water molecules	5, 10, 18	19
D. Explain the chemical processes involved with adhesion, cohesion, and surface tension	1, 2, 3, 14, 15	17
E. Relate the chemical processes of water to their importance for agriculture	6, 12, 13, 15, 18	33

Note: as some questions account for knowledge across objectives, point totals do not equal 100.

### Test Questions by Cognitive Level (Webb, insert year)

Webb Cognitive Level	Test Questions	Point Value
1	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 16	45
2	13, 15	8
3	14, 17, 18, 19	44
4	18	10

Note: as some questions may have differing cognitive levels based on student performance, point totals do not equal 100.

APPENDIX D

TEACHER AGREEMENT OF COMPLIANCE

## **Teacher Agreement of Research Compliance**

Texas A&M University Study on Cognitive Sequencing in Agricultural Education  
Classrooms

Principal Investigator: John Rayfield

Conducting Investigator: Kasee Smith

Thank you for your interest in serving as a participant in our research on cognitive sequencing in agricultural science classrooms. Please complete the following information to help us learn more about you and your program.

Name	
School	

### Teaching/Class Information

How many years have you been teaching?	
How many years have you been at your current school?	
How many Principles of AFNR class sections will you teach in the 2015-16 school year?	
How many students are expected to be enrolled in each of those class sections?	

### School/Community Information

What city is your school located in?	
What is the population of the city your school is located in?	
What is the estimated total school enrollment?	
Approximately how many students are enrolled in the agricultural education program at your school?	

### Assurances:

I hereby attest that I have completed the required training related to research protocol and test curriculum. I will administer the curriculum to my students exactly as outlined in the lesson plan, and will abide by all state, district, and Texas A&M University guidelines during this curriculum delivery.

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Signature

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Date

APPENDIX E

IRB APPROVAL DOCUMENTATION

(INITIAL AND AMENDMENT FOR ADDITIONAL SITES)

**DATE:** June 04, 2015

**MEMORANDUM**

**TO:** John Rayfield  
ALRSRCH - Agrilife Research - Ag Leadership, Education & Communication

**FROM:** Dr. James Fluckey  
Chair  
TAMU IRB

**SUBJECT:** Expedited Approval

**Study Number:** IRB2015-0234D

**Title:** A Quasi-experimental Study of the Impact of Cognitive Sequencing on Student Performance on STEM Content Assessments in Secondary Agriculture Science Courses

**Approval Date:** 06/04/2015

**Continuing Review Due:** 05/01/2016

**Expiration Date:** 06/01/2016

**Documents  
Reviewed and  
Approved:**

Submission Components			
Study Document			
Title	Version Number	Version Date	Outcome
Sit Authorization Rudder High School	Version 1.0	04/06/2015	Approved
Site Authorization A&M Consolidated High School	Version 1.0	04/06/2015	Approved
Kolb Learning Styles Inventory	Version 1.0	04/06/2015	Approved
Teacher Recruiting Application	Version 1.0	04/06/2015	Approved
Teacher Recruiting Email	Version 1.0	04/06/2015	Approved
Parental Consent Form	Version 2.0	04/10/2015	Approved
Student Assent	Version 1.0	04/06/2015	Approved

**Document of Consent:** Written consent in accordance with 45 CF 46.116/ 21 CFR 50.27

**Comments:** This application has been approved expedited.

**DATE:** 09/23/2015

**MEMORANDUM**

**TO:** John Rayfield

ALRSRCH - Agrilife Research - Ag Leadership, Education & Communication

**FROM:** Human Research Protection Program  
Institutional Review Board

**SUBJECT:** Amendment

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**Study Number:** IRB2015-0234D

**Title:** A Quasi-experimental Study of the Impact of Cognitive Sequencing on Student Performance on STEM Content Assessments in Secondary Agriculture Science Courses

**Date of  
Determination:**

**Review Type:** Process Administratively

**Approval  
Period:** 06/04/2015 to 06/01/2016

**Documents  
Reviewed and  
Approved:** Only IRB-stamped approved versions of study materials (e.g., consent forms, recruitment materials, and questionnaires) can be distributed to human participants. Please log into iRIS to download the stamped, approved version of all study materials. If you are unable to locate the stamped version in iRIS, please contact the iRIS Support Team at 979.845.4969 or the IRB Liaison assigned to your area.

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**Description of  
Submission:** IRB Amendment

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**Provisions:** Research cannot be conducted at the new sites until site authorizations have been submitted.

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**Comments:**

- Research is to be conducted according to the study application approved by the IRB prior to implementation.
- Any future correspondence should include the IRB study number and the study title.

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Investigators assume the following responsibilities:

750 Agronomy Road, Suite 2701  
1186 TAMU  
College Station, TX 77843-1186

Tel. 979.458.1467 Fax. 979.862.3176  
<http://rcb.tamu.edu>

APPENDIX F

PARENTAL CONSENT FORM



**Project Title: *A Quasi-experimental Study of the Impact of Cognitive Sequencing on Student Performance on STEM Content Assessments in Secondary Agriculture Science Courses***

Your student is enrolled in the Principles of Agriculture, Food, and Natural Resources with [insert teacher name] at [insert high school here]. This class is participating in a research study related to helping understand the best order for presenting information to students. Your student is invited to take part in a research study being conducted by John Rayfield and Kasee Smith, researchers from Texas A&M University. The information in this form is provided to help you decide whether or not your student should participate. If you decide you do not want your student to participate, there will be no penalty to you, and you will not lose any benefits you would normally have.

**Why Is This Study Being Done?**

The purpose of this study is to see how students with different learning styles best learn science concepts in agricultural science courses.

**Why Is My Student Being Asked To Be In This Study?**

Your student is enrolled in a Principles of AFNR class with a teacher participating in this research study.

**How Many People Will Be Asked To Be In This Study?**

All students enrolled in the Principles of AFNR classes from participating teachers will be instructed using research curriculum materials and invited to share test scores with research personnel. Overall, a total of approximately 180 people will be invited.

**What Are the Alternatives to being in this study?**

There are no alternatives to being in the study. Those electing not to have their student participate will have their scores excluded from the analysis.

**What Will My Student Be Asked To Do In This Study?**

Students will be asked to participate in their Principles of AFNR class as they would normally engage with class materials. For two subsequent units, the teacher will teach using curriculum materials developed by Texas A&M University researchers. This curriculum will be used as a replacement for the materials the teacher would regularly use to instruct the course. Students will complete classroom activities, worksheets, and tests that relate to the content taught. In addition, each student will be asked to take the 12 question Kolb Learning Styles Inventory assessment.

**Are There Any Risks To Me or My Student?**

The activities associated with this research pose no more risk than you or your student would come across in their typical agriculture classroom.

**Are There Any Benefits To Me or My Student?**

The direct benefit to your students from participating in this study is that they will be able to have access to their own learning style assessment. This could help them understand how they best learn information. In addition, they will be able to gain the knowledge of the information taught in the research curriculum units.

**Will There Be Any Costs To Me or My Student?**

Aside from the time required to complete assignments in class, there are no costs for taking part in the study.

**Will My Student or I Be Paid To Be In This Study?**

There is no payment for participation in this research.

**Will Information From This Study Be Kept Private?**

The records of this study will be kept private and anonymous. No identifiers linking your student to this study will be collected. Teachers will provide researchers your student's scores without a link to their name or any other identifying information. Only John Rayfield and Kasee Smith will have access to these anonymous records.

People who have access to your student's anonymous information include the Principal Investigator and research study personnel. Representatives of regulatory agencies such as the Office of Human Research Protections (OHRP) and entities such as the Texas A&M University Human Subjects Protection Program may access study records to make sure the study is being run correctly and that information is collected properly.

Information about you and related to this study will be kept confidential to the extent permitted or required by law.

**Who May I Contact for More Information?**

You may contact the Principal Investigator, John Rayfield Ph.D., to ask any questions about this study or tell him about a concern or complaint with this research at 979-862-3707 or [jrayfield@tamu.edu](mailto:jrayfield@tamu.edu). You may also contact the Protocol Director, Kasee Smith at 801-598-8027 or [kasee.smith@ag.tamu.edu](mailto:kasee.smith@ag.tamu.edu).

For questions about your rights as a research participant; or if you have questions, complaints, or concerns about the research, you may call the Texas A&M University Human Subjects Protection Program office at (979) 458-4067 or [irb@tamu.edu](mailto:irb@tamu.edu).

**What if I Change My Mind About My Student Participating?**

This research is voluntary and you have the choice whether or not to have your student be a part of this research study. You may decide to not begin or to stop participating at any time. If you choose not to be in this study or stop being in the study, there will be no effect on your relationship with Texas A&M University or state staff in your state.

*If you consent to your student's participation, please return the attached form.* Your student's scores will not be included unless the consent form is returned.

Thank you,  
**John Rayfield, PhD**

Complete and Return to Agricultural Science Teacher to allow your student's scores to be included in this study.

## Parental Consent

I give permission for researchers to include my student's anonymous test scores in this research study. I understand they will still have access to the curriculum taught during these units and their course grade will be in no way affected if I choose not to sign this consent.

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Student Name

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Parent Signature

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Date

APPENDIX G  
STUDENT ASSENT

Dear Student,

We are interested in understanding more about how the order of information being presented to you in class affects your learning. You are currently enrolled in a Principles of Agriculture, Food, and Natural Resources class that teaches science concepts in agriculture. Researchers at Texas A&M University would like to study how the order of teaching items helps you learn. As part of this research, you will be asked to do three things:

1. Take a twelve question Learning Style Inventory.
2. Complete a unit on Water Science that your teacher will instruct.
3. Complete a unit on Soil Science that your teacher will instruct.

Your parent/guardian has been sent the information about this project. You are not required to participate in this research. You may elect to have your scores not recorded by the researchers at any time.

As researchers, we will not have access to your name. Any scores that we receive will have only a number, and we will have no way of tracing your scores back to you as an individual. If you have any questions about the study or what you are asked to do, please ask us. Thank you for your help with this project.

Sincerely,

Kasee L. Smith  
Graduate Student, Texas A&M University

John Rayfield, Ph.D.  
Professor, Texas A&M University

I have read this form and agree to help with this research project.

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Print Name

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Signature

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Date